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THE
LABYRINTH OF ANIMALS

VOLUME II.

THE LABYRINTH OF ANIMALS

INCLUDING MAMMALS, BIRDS, REPTILES AND AMPHIBIANS

BY

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VOLUME II.

TEACHING AND RESEARCH LABORATORY, MAUDSLEY HOSPITAL MEDICAL SCHOOL.

LONDON
J. & A. CHURCHILL
7 GREAT MARLBOROUGH STREET
1908

PRINTED BY
SPOTTISWOODE AND CO. LTD., NEW-STREET SQUARE
LONDON

PREFATORY NOTE TO VOLUME II

THE Author has to thank the Carnegie Trust for their liberal generosity in assisting him in the publication of the second volume.

He again tenders his thanks to the Zoological Society of London for the rich supply of material which they have given him.

GLASGOW : *November* 25, 1907.

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THE LABYRINTH OF ANIMALS

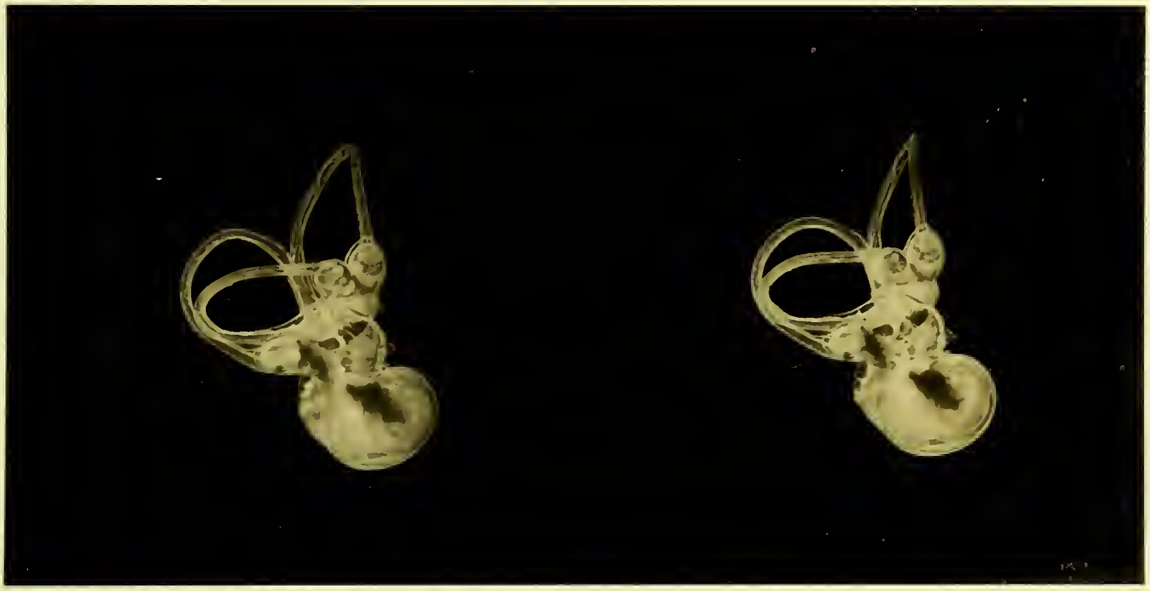
PLATE I

THE RIGHT MEMBRANOUS LABYRINTH OF THE COMMON SQUIRREL

Sciurus vulgaris.

× 6

The organ is suspended from the superior canal and is viewed from below and in front. Pigment is seen in the ampullæ and there is practically no perilymph space in the canals. The cochlea is of the sharp-pointed type, and there is a considerable bulging of the floor of the scala tympani in the region of the aqueduct of the cochlea.



RODENTIA—*continued*

THE MEMBRANOUS LABYRINTH OF THE COMMON SQUIRREL

Sciurus vulgaris

The labyrinth of the squirrel is in many respects similar to those of the other rodents, but is on the whole more delicate as regards the semicircular canals. The cochlea is of the sharp-pointed type, and the semicircular canals have no perilymph space except at the angles formed by the ampullæ with the canals proper.

The organ measures 7.5 mm. from the outermost point on the vertex of the posterior canal to the innermost point on the lowest whorl of the cochlea. The diameter of the lowest whorl of the *cochlea* is 3.25 mm., and that of the second 2.25 mm. The diameter of the tube of the cochlea just in front of the round window is 1.75 mm., and the slant height of the organ from the upper margin of the round window to the apex is 2.75 mm. There are two and three-quarter turns in the cochlea ; and a considerable bulging of the floor of the scala tympani in the region of the aqueduct is visible.[1]

The *vestibule* measures 3.0 mm. in its longest diameter, and there are no otoliths of size sufficient to be recognised by the naked eye. The oval window has a major axis of 1.5 mm., and is thus actually longer than that of the hare, though the animal itself is considerably smaller. In the squirrel, however, the oval window is a particularly long and narrow ellipse, so that the actual area of the opening is greater in the hare. The aqueduct of the cochlea is a very fine tube, and breaks readily in the process of preparation, differing in this respect therefore from those of the rabbit and the hare and resembling that of the capybara.

---

[1] For the interesting phylogenetic significance of this bulging of the floor of the scala tympani, see p. 108.

The semicircular canals of the squirrel are very delicate and beautifully curved, and the perilymph space is almost absent in this portion of the labyrinth. In proportion to the rest of the labyrinth the canals are, on the whole, rather large. The *superior canal* measures 4.0 mm. in internal, and 5.0 mm. in external diameter. The height of the vertex of the canal above the vestibule is 3.0 mm., and the diameter of the canal itself at the vertex is rather less than 0.5 mm. The *posterior* is distinctly smaller than the superior or horizontal canals, measuring 2.5 mm. in internal, and rather more than 3.25 mm. in external diameter. The height of its vertex above the vestibule is 2.5 mm., and the diameter of the canal itself at the vertex is rather less than 0.5 mm. The internal diameter of the *horizontal canal* is 3.0 mm. and its external diameter rather more than 3.75 mm. The height of the vertex of the canal above the vestibule is 2.5 mm., and its diameter at the vertex is rather less than 0.5 mm. The plane of the horizontal canal is low, being in this respect similar to that of most mammals. The posterior limb of the canal opens into the perilymph space of the posterior ampulla, as is also frequently the case in the mammalia.

Pigment is found in the labyrinth of the squirrel in the region of the ampullæ. It is in the form of a crescentic patch, which partially surrounds the ampulla at the point at which the latter is becoming narrowed down to pass into the canal proper. This is, of course, the position in which pigment is most usually found in mammalia, but in the case of the squirrel the patch has not quite the sharply defined outline which it posseses in some animals, such as the baboon and the green monkey. No pigment is found in the vestibule, and in the cochlea there is very little, the labyrinth being in this respect unlike that of the jerboa.

LITERATURE.—Hyrtl, *Inner. Gehör. d. Mensch. u. Säugeth.* S. 26, 65, &c., 1865.

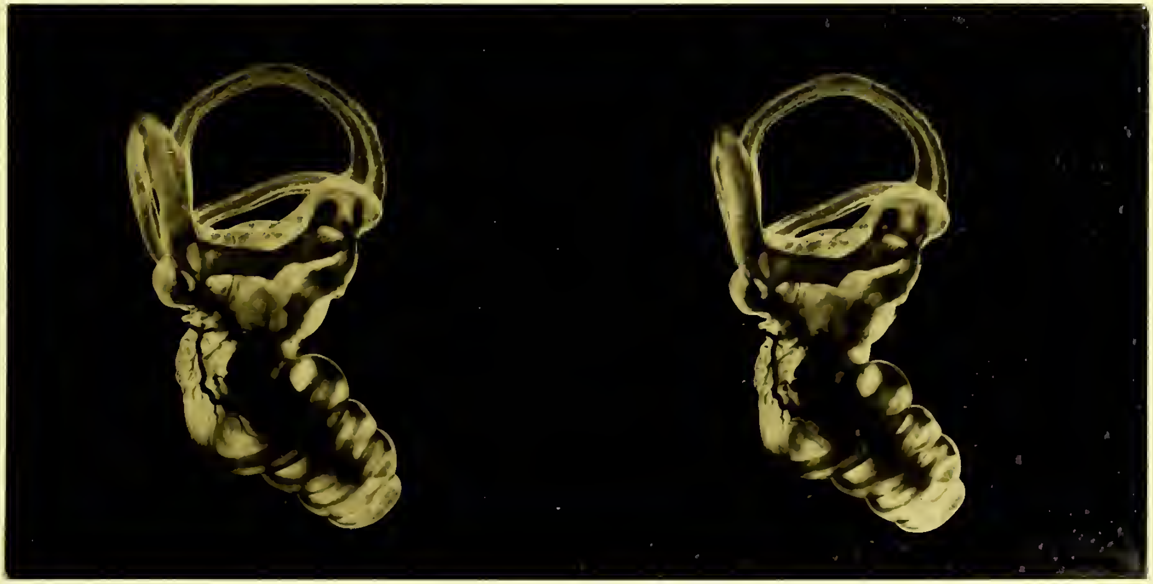
PLATE II

THE LEFT MEMBRANOUS LABYRINTH OF THE CAPYBARA

Hydrochoerus capybara

× 4¼

The organ is suspended by the superior canal and is viewed from the inner aspect. A rich deposit of pigment is present on the upper surface of the utricle, on the ampullæ and along the common crus of the superior and posterior canals. Pigment is also seen in the region of the ligamentum spirale of the very sharp-pointed cochlea. A large vein is seen leaving the labyrinth in company with the narrow aqueduct of the cochlea. The perilymph space is fairly well marked in the canals.



RODENTIA

THE MEMBRANOUS LABYRINTH OF THE CAPYBARA

Hydrochoerus capybara

The labyrinth of the capybara is one of the most curious among those of the mammalia. This is for the most part owing to the shape of the cochlea, which is the most extreme example of the sharp-pointed type that has been found, and to the fact that the pigment in the vestibule is distributed in a very peculiar way.

The whole organ measures 14.5 mm. from the outermost point on the vertex of the posterior canal to the innermost point on the lowest whorl of the cochlea. The *cochlea* has a diameter of 7.5 mm., while the second whorl has a diameter of 4.5 mm. The diameter of the tube of the cochlea just in front of the round window is 2.5 mm., and there is in this region a bulging of the floor of the scala tympani similar to that found in a more marked degree in many of the other mammalian orders. The aqueduct of the cochlea is a very fine tube, and breaks in the process of preparation. The stump of it may, however, be seen in the photograph, along with the vein which accompanies it out of the labyrinth. A fairly well-marked band of pigment is found along the outer wall of the tube of the cochlea, the amount of pigment diminishing with the ascent of the spiral until in the uppermost whorl it can hardly be seen. There are more than four and a quarter turns in the cochlea, this being the largest number which has been recorded in any animal, and the resulting sharp-pointed appearance of the organ is very characteristic. The slant height of the cochlea is 6.0 mm.

The *vestibule* measures 5.0 mm. in its longest diameter, and contains no otoliths of a size sufficient to be recognised by the naked eye. The oval window has a major axis of 2.0 mm., and is proportionately broader than that of the squirrel.

The canals are relatively not so long as in the squirrel, but are much thicker. The superior and horizontal are of almost exactly the same dimensions, and the posterior is smaller than the other two. The *superior canal* measures 5.5 mm. in internal, and 7.5 mm. in external diameter. The height of the vertex of the canal above the vestibule is 4.75 mm., and the diameter of the canal itself at this point is rather less than 1.0 mm. The *posterior canal* measures 4.75 mm. in internal, and 6.5 mm. in external diameter. The height of the vertex of the canal above the vestibule is 4.5 mm., and its diameter at the vertex is 1.0 mm. The *horizontal canal* has an internal diameter of 5.5 mm. and an external one of 7.5 mm. The height of the vertex of the canal above the vestibule is 3.5 mm., and its diameter at this point is 1.0 mm. Thus the horizontal is shallower in the arch than the superior or posterior canals. The perilymph space is fairly well marked in all the canals, the labyrinth being in this respect in marked contrast with that of the squirrel.

The distribution of the pigment in the vestibule and canals is very peculiar. In each of the ampullæ there is a crescentic deposit of pigment in the neck which separates the ampulla from the canal proper, an arrangement very similar to the deposit which is found in the same situation in the baboon, the green monkey, and several others of the mammalia. The other neck which separates the ampulla from the vestibule is also the seat of a pigmentary deposit, but the pigment is not limited to this position, and extends from the ampulla over a large portion of that part of the upper surface of the vestibule which is formed by the utricle. Thus, as may be seen from the photograph, a band of pigment runs from the ampullæ of the superior and horizontal canals backwards to the opening of the common limb of the posterior and superior canals. This band of pigment is sharply defined, and is confined to the utricle, there being no pigment in the wall of the saccule. The deposit is clearly in the wall of the endolymph cavity, the endosteum showing no pigment at all. About the middle of the band of pigment there is a conical projection downwards; at its posterior extremity it unites with that from the ampulla of the posterior canal, and from this point the deposit of pigment is carried upwards along the anterior and external surfaces of the common limb of the superior and posterior canals, and stops at their junction.

It is interesting to note that, so far as present investigations go, the rodents possess the two examples among the mammalia in which pigment is found in greatest abundance in the labyrinth. In the jerboa it is found most abundantly in the cochlea, while in the capybara it is found most abundantly in the canals and vestibule.

The aqueduct of the cochlea in the capybara is extremely delicate and breaks in the process of preparation.

LITERATURE—Hyrtl, *Op. cit.* S. 25. Denker, *Das Gehörorgan d. Säugethiere.* S. 51, 1899.

INSECTIVORA

Anatomists are agreed in considering the insectivora to be an ancient race, and the study of the labyrinth is certainly in favour of the correctness of this conjecture. The organ shows evidence of more ancient characteristics than that of any other order of mammals with the exceptions of the monotremata, sirenia, cetacea, and a few of the polyprotodont marsupials. Unfortunately for our present purpose, the majority of the animals of this order are very small, and their labyrinths do not therefore lend themselves to examination. The writer has had an opportunity of investigating two species only, the common mole and the hedgehog, and it would be interesting to obtain further knowledge of the order. Of the two mentioned, the hedgehog appears to possess the more ancient type of labyrinth. It is rather curious to note that in neither of these animals is pigment found in the labyrinth. In both animals the number of turns in the cochlea is small. The chief distinguishing feature is to be found in the canals, those of the mole being long and thin, while those of the hedgehog are short and thick. Further, there is a well-developed perilymph space in the canals of the latter, whereas in those of the mole this is hardly to be seen. This is another reason for considering the labyrinth of the hedgehog to be of an earlier type.

In the insectivora the cochlea is of the flat type, at least so far as present investigations show, but it is important that further examination of the labyrinths of this order should be undertaken.

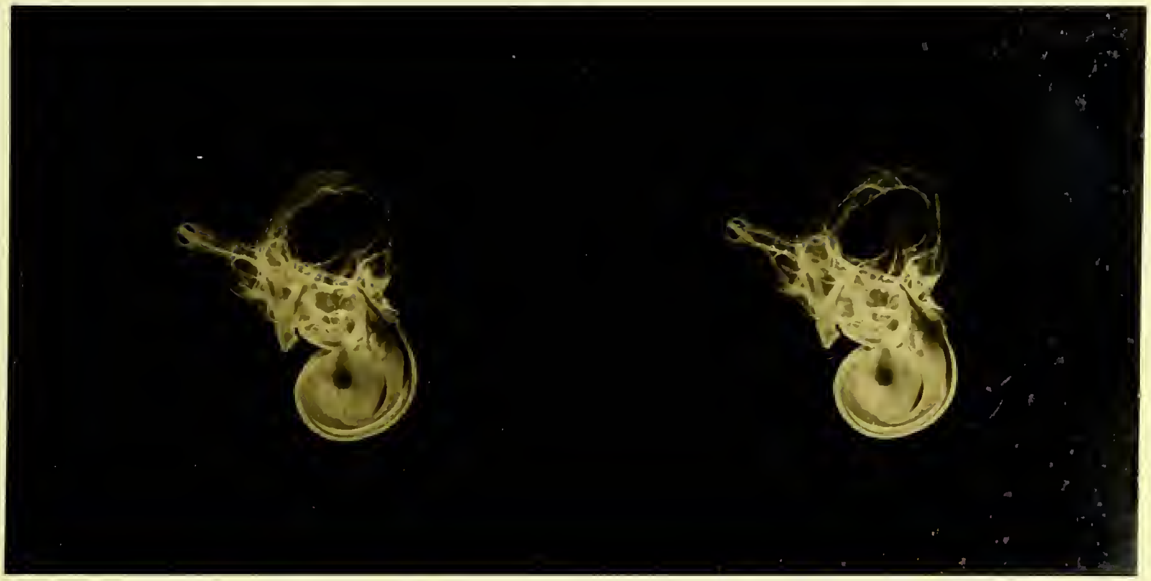
PLATE III

THE LEFT MEMBRANOUS LABYRINTH OF THE HEDGEHOG

Erinaceus europæus

× 6

The organ is suspended by the horizontal canal and is viewed from in front ; it is also rotated a little counter-clockwise. The canals are thick, the perilymph space is well marked, and the ampullæ are rather small. There are barely one and a half turns in the cochlea. No pigment is present in the labyrinth, the black markings in the spirals of the cochlea to the right being due to the presence of blood.



INSECTIVORA

THE MEMBRANOUS LABYRINTH OF THE HEDGEHOG

As remarked above, the labyrinth of the hedgehog shows evidence of a very ancient type. The cochlea possesses only one and a half whorls, and there is a well-developed perilymph space in the canals. The only other mammals examined in which there are so few turns in the cochlea are the sea-cow, the marsupial mole, and the platypus.

The whole organ measures 6.5 mm. from the outermost point on the vertex of the posterior canal to the innermost point on the lowest whorl of the *cochlea.* The latter has a diameter of 3.0 mm., and the second whorl a diameter of 1.75 mm. The diameter of the tube of the cochlea just in front of the round window is 1.5 mm., and there is no very marked bulging of the floor of the scala tympani in this region, such as is found in many of the mammalia. The aqueduct is short but relatively thick. The slant height of the cochlea measured from the apex to the upper margin of the round window is 2.5 mm. The cochlea is of the flat type, as might be expected from the small number of whorls.

The *vestibule* measures rather less than 2.5 mm. in its longest diameter, and the major axis of the oval window is 1.0 mm. in length. Two small otoliths are seen in the vestibule ; these appear as white specks in the photograph. The oval window is kidney-shaped. The aqueduct of the vestibule is comparatively thick, and may be preserved in the process of preparation. It may be seen in the photograph behind the common limb of the posterior and superior canals. No pigment is found in the vestibule.

The canals of the hedgehog are comparatively thick, and their perilymph spaces are very well marked. They bear a close resemblance to the canals of some of the monkeys. The *superior canal* measures 2.75 mm. in internal, and 3.5 mm. in external diameter. The height of the vertex of the canal above the vestibule is 3.0 mm., and the diameter of the canal itself at the vertex is 0.5 mm. The *posterior canal* has internal and external diameters of 2.0 mm. and 3.0 mm. respectively. The height of the vertex of the canal above the vestibule is 2.0 mm., and the diameter of the canal itself at the vertex is 0.5 mm. The *horizontal canal* measures 2.0 mm. in internal, and 3.25 mm. in external diameter. The height of the vertex of the canal above the vestibule is 2.0 mm., and the diameter of the canal itself at the vertex is 0.5 mm.

The canals of the hedgehog are rather more widely divergent than in many animals. The plane of the horizontal canal is low, and at its posterior extremity the perilymph space opens into that of the posterior canal. In the disposition of the posterior and horizontal canals there is a marked difference between the hedgehog and the mole. In the former there is no communication between the two canals except at the ampulla of the posterior canal, a condition common in the mammalia ; in the mole, on the other hand, there is a communication between the two canals at the point at which they cross, a feature very rare in mammals, although it is the common disposition in birds and reptiles. The only other mammals in which this arrangement has been found are the marsupial mole, the jerboa mouse, and possibly the dromedary. The matter will be referred to again when describing the marsupial labyrinth.

No pigment is found in the canals of the hedgehog.

LITERATURE.—Hyrtl, *Op. cit.* S. 62, 86, &c. Denker, *Op. cit.* S. 26.

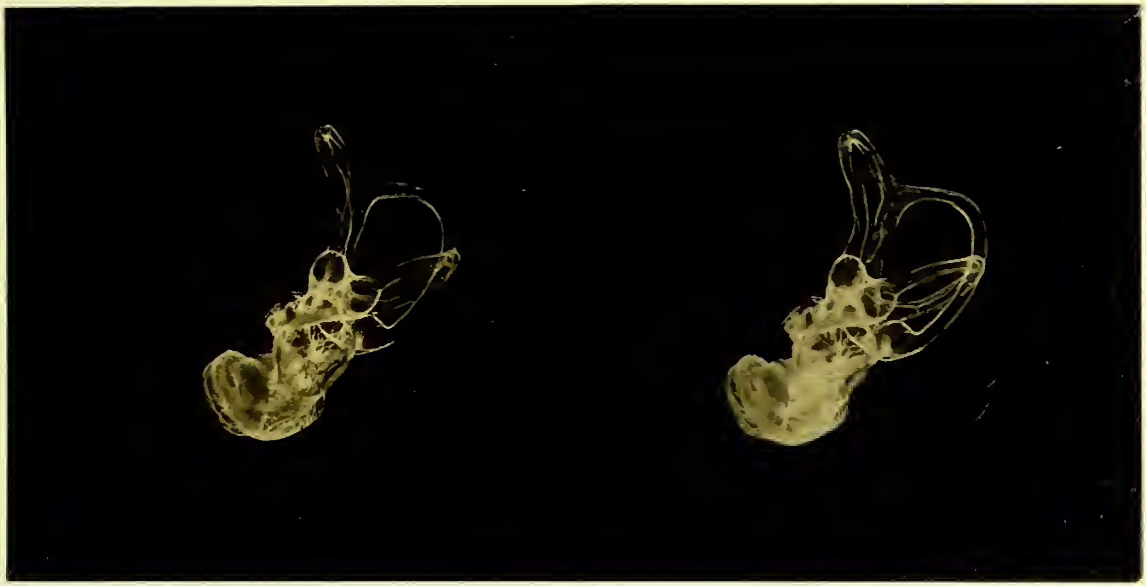
PLATE IV

THE LEFT MEMBRANOUS LABYRINTH OF THE COMMON MOLE

Talpa europæa

× 8

The organ is suspended from the superior canal and is viewed from in front. The canals are comparatively long, and there is a communication between the posterior and horizontal canals, a very rare feature in the mammalia. The cochlea is of the flat type, and there are one and three-quarter turns in the organ. The blood-vessels are very much dilated.



INSECTIVORA

THE MEMBRANOUS LABYRINTH OF THE COMMON MOLE

There are considerable differences to be found between the labyrinths of the hedgehog and the mole. In the mole the organ as a whole is longer and more delicate, and the canals in particular are thinner than in the hedgehog.

The organ measures 5.0 mm. in length from the outermost point on the vertex of the posterior canal to the innermost point on the lowest whorl of the cochlea. The lowest whorl of the *cochlea* measures rather less than 2.0 mm. and the second 1.0 mm. in diameter. The diameter of the tube of the cochlea just in front of the round window is 0.75 mm., and there is a slight bulging of the floor of the scala tympani in this region. The aqueduct of the cochlea is very fine, and breaks in the process of preparation. The organ is of the flat type, and the slant height, measured from the upper margin of the round window to the apex, is rather more than 1.5 mm. There are one and three quarter turns in the cochlea, and no pigment is to be found in the organ.

The *vestibule* measures 1.75 mm. in its greatest diameter, and contains no otoliths of a size sufficient to be recognised by the naked eye. The oval window measures 0.5 mm. in its major axis; no pigment is found in the vestibule. The aqueduct of the vestibule is a very fine thread, and breaks in the process of preparation.

The canals are all very delicate, and there is little or no evidence of a perilymph space in any of them. The *superior* is the largest of the three, measuring 2.25 mm. in internal, and 3.0 mm. in external diameter. The height of the vertex of this canal above the vestibule is rather more than 2.75 mm., and the diameter of the canal itself at the vertex is a little more than 0.25 mm. The *posterior* is smaller than the superior canal, and measures 1.5 mm. in internal, and 2.25 mm. in external diameter. The height of its vertex above the vestibule is 2.25 mm., and its diameter at the vertex is rather more than 0.25 mm. The *horizontal canal* has internal and external diameters of 1.5 and 2.25 mm. respectively. The height of the vertex above the vestibule is 2.0 mm., and the diameter at the vertex is rather more than 0.25 mm. Thus the horizontal and posterior canals are of almost exactly the same dimensions, and both are smaller than the superior.

No pigment is found in the canals, even in the ampullæ, the mole being one of the few mammals that are without any evidence of pigment anywhere in the labyrinth. The canals are not set at such divergent angles as they are in the hedgehog, and the horizontal canal is relatively on a slightly higher plane. There is a communication between the posterior and the horizontal canals which has already been alluded to, and which may be seen in the photograph. The only other mammals which certainly possess this communication are the marsupial mole and the jerboa mouse (v. p. 65, 66, vol. ii). It is possible that in the dromedary the same condition may exist, but it is not so definitely present as in these other animals (v. p. 145, vol. i.).

As stated above, the canals of the mole are thinner and more delicate than those of the hedgehog, owing for the most part to the fact that in the latter there is a well-marked perilymph space, while in the mole there is none. But even apart from this distinction the canals appear longer in proportion to the whole labyrinth in the mole than in the hedgehog, and this is particularly true of the superior canal.

In the photograph of the labyrinth of the mole on page 18, the veins are well shown. This is owing to the fact that the animal was killed by strangulation, and the veins of the head were consequently engorged at the moment of death.

LITERATURE.—Hyrtl, *Op. cit.* 46, 77, &c. Alexander, *Zeitschr. f. Psycholog. u. Physiolog. d. Sinnesorgane*, Bd. xxxviii. Hft. 1, 1905.

CETACEA AND SIRENIA

It is admitted by anatomists to be difficult to assign to the sirenia and cetacea their true position in the mammalian stem. Cuvier placed the two orders in one, and called the sirenia cetacea herbivora. In more recent times, however, the consensus of opinion has been that the similarities which exist between the two orders are owing to changes of an adaptive kind. It has been suggested that the sirenia and cetacea are related most closely to the ungulates; and an affinity with the edentata has also been claimed for the cetacea. It may, of course, be that one of these suggestions is correct; but in neither case does the appearance of the labyrinth lend them much support. In both the cetacea and the sirenia the cochlea is of a very primitive type.

Of the two orders it is difficult to say which should be regarded as the more ancient. If we were to judge by the appearance of the cochlea, which, it is to be remembered, is more to be relied upon than the vestibule or the canals, and indeed is an organ which should have more weight than almost any other in considerations such as the present (v. p. 20, vol. i.), then the sirenia would undoubtedly be entitled to claim a greater antiquity. In this order the cochlea has only one and a half turns, whereas among the cetacea the porpoise has one and three quarters, and the whale two turns. In the sirenia, moreover, the round window merges into the aqueduct of the cochlea.

As regards the vestibule and canals, there is no doubt that in the cetacea these organs have undergone more modification than in the sirenia. Indeed, in no other mammal have the organs referred to been subjected to so much change. The cause of this transformation appears to the writer to be the ankylosis of the cervical vertebræ which is so marked a feature in the anatomy of the cetacea. There seems to be little doubt that, at any rate in mammals, the functions of the canals and vestibule are correlated in some way with the extent and delicacy of the movements of the head upon the trunk, and it is probably in accordance with this fact that the canals of the cetacea have undergone such modifications. In the dugong, from which the present description of the labyrinth of the sirenia is taken, the cervical vertebræ are not ankylosed, and there is not so much evidence of the modification of the canals and vestibule as is found in the cetacea. Still, even in the dugong there is a clear diminution in size of these structures in proportion to the rest of the labyrinth, and it seems to the writer that this is to be associated with the limited movements of the head upon the trunk which are characteristic of the animal. An examination of the labyrinth of the manatee would be interesting, since in this species of the sirenia the second and third cervical vertebræ are fused together, and there is probably a more restricted movement of the head upon the trunk than in the dugong.

There are other points of similarity between the labyrinths of the sirenia and the cetacea besides those already mentioned. In both the cochlea is of the flat type, although this may not be allowed very much weight where the number of turns is so few that a sharp-pointed type of the organ could hardly exist. Still, even in this feature differences may occur, as may be seen in the case of the marsupial mole, where it is clear that the cochlea is in the early stage of the sharp-pointed type, in spite of the fact that there are only one and a half turns. Otoliths sufficiently large to be recognised by the naked eye are found in both the cetacea and the sirenia, and in both they are to be found in the same position in the vestibule. Pigment is present in the cochlea of both orders in the usual place, and in both it is absent from the ampullæ of the canals.

The differences which are found between the two orders under discussion are :—the fewer number of turns in the cochlea of the sirenia, the greater disproportion in size between the vestibule and canals and the cochlea in the cetacea, and the presence in the latter order of a deep cleft between the scala tympani and scala vestibuli, which is absent in the sirenia. Further, the curvature of the cochlea is much more regular in the cetacea than in the sirenia, in which the lower whorl of the organ is roughly quadrilateral. In the sirenia there is a curious conical projection of the perilymph space below and in front of the ampullæ of the superior and horizontal canals which is not found in the cetacea or in any other order of mammals. The perilymph space of the canals is not well-marked in either the cetacea or the sirenia, but, in both, this may merely be due to the general diminution in size of these structures. In the sirenia the space is easily seen, but in the cetacea it is not visible at all.

The aqueduct of the cochlea is very different in the two orders. In the cetacea it appears as a long and relatively thick tube somewhat similar to the same structure as it is found in some other mammals. In the sirenia, on the other hand, the aqueduct is not completely surrounded by bone. The peculiar anatomical disposition of this portion of the labyrinth of the latter order is given on the following pages, and it need only be noted here that it differs from that in the cetacea and all other mammals

CETACEA

THE LABYRINTH OF THE WHALE

Balæna australis

It was most unfortunate that, when the temporal bones of the whale reached the writer, putrefaction was far advanced and all the soft structures were in such a state of disintegration that, after preparation, only a somewhat discoloured cast of the labyrinth was obtained. From this cast the measurements given below were taken, but the membranous structures had been so far destroyed by the putrefactive process that no satisfactory photograph was obtainable. From what could be seen the labyrinth differed from that of the porpoise only in size.

This labyrinth is the largest of all those which have been examined hitherto, and measures 25 mm. in extreme length from the outermost point on the horizontal canal to the innermost point on the lowest whorl of the cochlea. The diameter of the lowest whorl of the enormous *cochlea* is 20.5 mm., and that of the second whorl 12.5 mm. The diameter of the tube of the cochlea just in front of the round window is 4.5 mm.

The *vestibule* measures 6.0 mm. in its longest diameter, and the major axis of the oval window has a length of 6.0 mm.

Thus the oval window extends the whole length of the outer wall of the vestibule.

The *superior canal* measures 5.0 mm. in internal, and 7.5 mm. in external diameter. The height of the vertex of the canal above the vestibule is 5.0 mm., and the diameter of the canal itself at the vertex is 0.75 mm. The *posterior canal* measures 3.5 mm. in internal, and 5.5 mm. in external diameter. The height of the vertex of the canal above the vestibule is 4.5 mm., and the diameter of the canal itself at the vertex is 0.75 mm. The *horizontal canal* has internal and external diameters of 6.5 mm. and 9.5 mm. respectively. The height of the vertex of the canal above the vestibule is 5.0 mm., and the diameter of the canal itself at the vertex is 0.75 mm. Thus the horizontal is the largest of the canals and the posterior the smallest, the labyrinth in this respect differing from those of all other mammals except the porpoise.

The cochlea has two turns, and the slant height of the organ from the front of the round window to the apex is 13.0 mm.

LITERATURE.—Hyrtl, *Die Corrosions-Anatomie u. ihre Ergebn.* S. 234. Wien, 1873. Beauregard, *Journ. de l'Anatom. et de la Physiolog.*, 1893, p. 183. Denker, *Arbeit. aus d. anatomisch. Institut*, Bd. xix. Boenninghaus, *Das Ohr des Zahnwales.* G. Fischer, Jena, 1903.

PLATE V

THE LEFT MEMBRANOUS LABYRINTH OF THE COMMON PORPOISE

Phocæna communis

× 5½

The organ is suspended by the superior canal and is rotated a little clockwise; it is viewed from in front. The canals and vestibule are very small. There is a deep cleft between the scala tympani and the scala vestibuli. The veins are seen very clearly passing inwards over the upper surface of the whorls towards the modiolus. The intracranial end of the aqueduct of the cochlea is just seen at the back at the left lower part of the photograph.

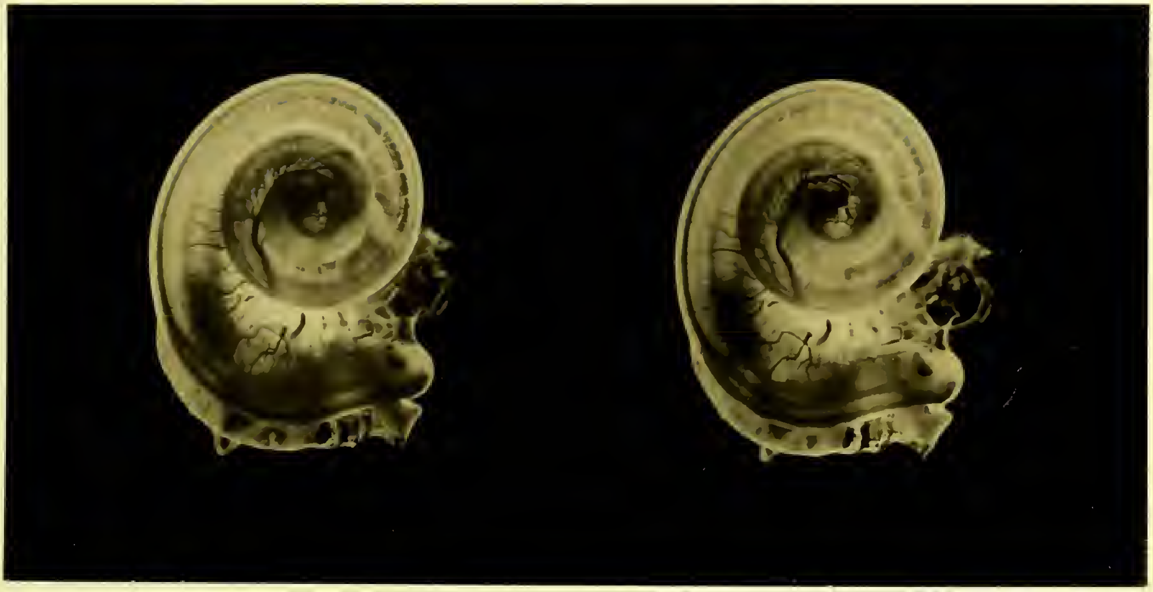


PLATE VI

THE RIGHT MEMBRANOUS LABYRINTH OF THE COMMON PORPOISE

Phocæna communis

× 5

The organ has been fixed with chromic and osmic acids in order to show the nerves to the ampullæ. The oval window is seen immediately below the ampulla of the horizontal canal.

CETACEA

THE MEMBRANOUS LABYRINTH OF THE PORPOISE

Phocæna communis

The labyrinth of the porpoise is embedded in a separate bone termed the periotic bone, which is movable upon the rest of the skull. The fact that this bone is only attached to the skull by means of ligaments was mentioned by Cuvier, and it may have been known before his time, though no reference has been found to indicate this. The ligaments allow of a movement round an axis which lies a little behind the bone, and the extent of this movement at the lower and anterior surface amounts to several millimetres.

In the membranous labyrinth the most obvious peculiarity is the remarkable disproportion between the cochlea on the one hand, and the canals and vestibule on the other. Such a marked difference in size has not been found in any other order of mammals.

The extreme length of the labyrinth is 9.5 mm. The diameter of the lowest whorl of the *cochlea* is 8.5 mm., that of the second being 4.5 mm. The diameter of the tube of the cochlea immediately in front of the round window is 3.0 mm. The aqueduct of the cochlea is a rather thick tube measuring about $\frac{3}{4}$ mm. in its greatest diameter : it is directed backwards and inwards, and is of nearly uniform thickness throughout. The distance of the upper margin of the round window from the apex of the cochlea is 6.5 mm.

A deep cleft runs along the outer border of the tube of the cochlea, a condition which occurs, so far as the writer knows, in no other order except to a slight extent in the marsupials. This cleft, according to Denker, occupies the space which is filled in the recent state by the ligamentum spirale. His conclusion was the natural one when it is remembered that his work was done on corrosion preparations. It is, however, quite incorrect, as may be seen at once when the membranous labyrinth itself is examined. The ligamentum spirale of the porpoise lies above this cleft, and in its lower portions presents the appearance of a thin band. The band is continued in the usual way right up to the apex of the cochlea, gradually becoming more and more faint as it ascends. Though the cleft referred to by Denker does not represent the space occupied by the ligamentum spirale, it may be that the fibres of that structure are attached to the bone which undoubtedly fills it in the recent condition. It should be added that the cleft rapidly diminishes in size as it ascends the cochlea.

The turns of the cochlea number one and three-quarters, the divisions between them are well marked, and the organ is of the flat type. A vein of considerable size leaves the labyrinth by way of the aqueduct.

The *vestibule* of the porpoise is a small cavity measuring about 1.25 mm. in diameter. In spite of its smallness, however, it is of interest from its containing two relatively large otoliths. These are not, of course, so large as those of the fish, but are about the size of those found in the bird, and, indeed, are not at all unlike them in shape. The larger of the two lies a short distance behind the ampullary openings of the superior and horizontal canals, and the smaller lies below it ; both are milk-white in colour. The comparatively large size of these otoliths naturally recalls the similar structures in the seal, though in the latter animal they are even larger and are placed more widely apart. The aquatic life of both animals may possibly be associated in some way with the size of the otoliths. In the case of the porpoise, it may be noted that the cetacea are probably more closely related to the reptiles than most of the mammals, and have not quite lost the resemblance to these animals as regards the otoliths. The similarity of the otoliths of the porpoise to those of the birds suggests this relationship.

Although the vestibule of the porpoise is very small, the diameter of the oval window in its longest axis is 1.25 mm., so that the aperture into the cavity is as long as the cavity itself, or nearly so.

The canals of the porpoise are all very small, but in proportion to their size they are rather thick. The internal diameter of the *superior canal* is 1.5 mm., while the external diameter is 2.0 mm. or rather less. The height of the vertex of the canal from the vestibule is nearly 1.25 mm., and the diameter of the canal itself at the vertex is 0.5 mm. Thus, while in length the canal is of almost the same size as that of the mouse, it is in thickness equal to that of the lemur. The *posterior canal* is much the smallest of the three ; its internal diameter is 0.75 mm., and its external diameter is not quite 1.5 mm. The height of the vertex of the canal from the vestibule is rather more than 0.5 mm., and its diameter at the vertex is not quite 0.5 mm. The posterior canal presents the peculiarity of being fused with the posterior limb of the horizontal canal, and its openings into the vestibule are shared by the superior canal above, and the horizontal canal below. The *horizontal canal* is the largest of the three, its internal diameter being 1.75 mm., and its external 2.25 mm. The height of this canal from the vestibule to the vertex is 1.25 mm., and the diameter of the canal itself at the vertex is 0.5 mm. Thus the horizontal canal is the largest and the posterior is the smallest of the three, a relationship which is unique among the mammals examined.

Each of the canals lies fairly accurately in one plane, there being little or no twisting. The ampullæ are not well developed, in fact they can hardly be termed ampullæ; but each is supplied with a nerve, though Denker was unable to find those to the superior and horizontal ampullæ.

The aqueduct of the vestibule is a very fine thread, and breaks in the process of preparation.

A little pigment is present in the region of the spiral ligament of the cochlea, but none is found in the ampullæ.

LITERATURE.—Claudius, *Physiolog. Bemerk. über d. Gehör. d. Cetacea, &c.* S. 8. Kiel, 1858. Ibsen, *Anat. Undersøgelser over Øretslabyrinth.* S. 41. Copenhagen, 1881. Hyrtl, *Inner. Gehör. d. Mensch. u. Säugeth.* S. 38, 59, 73. Denker, *Arbeit. aus d. Anatom. Instit.* Bd. xix.

PLATE VII

THE RIGHT MEMBRANOUS LABYRINTH OF THE DUGONG

Halicore australis

× 3¼

The organ is viewed from below and in front, and the horizontal canal is the nearest of the three to the reader. The canals are all very small, and the perilymph space is not very well marked, though it can be traced all round the canals. The ampullæ also are small and the cristæ acusticæ are poorly developed. It will be seen that a nerve twig passes from the branch to the ampulla of the horizontal canal across to the ampulla of the superior canal. There is a conical bulging of the utricle immediately below the ampulla of the superior canal, and the nerves to the ampullæ pass through this bulging portion. The oval window is large and the ellipse which it forms is narrow. The cochlea is large and rather irregular in curvature, and only possesses one and a half turns. The round window is also very large.

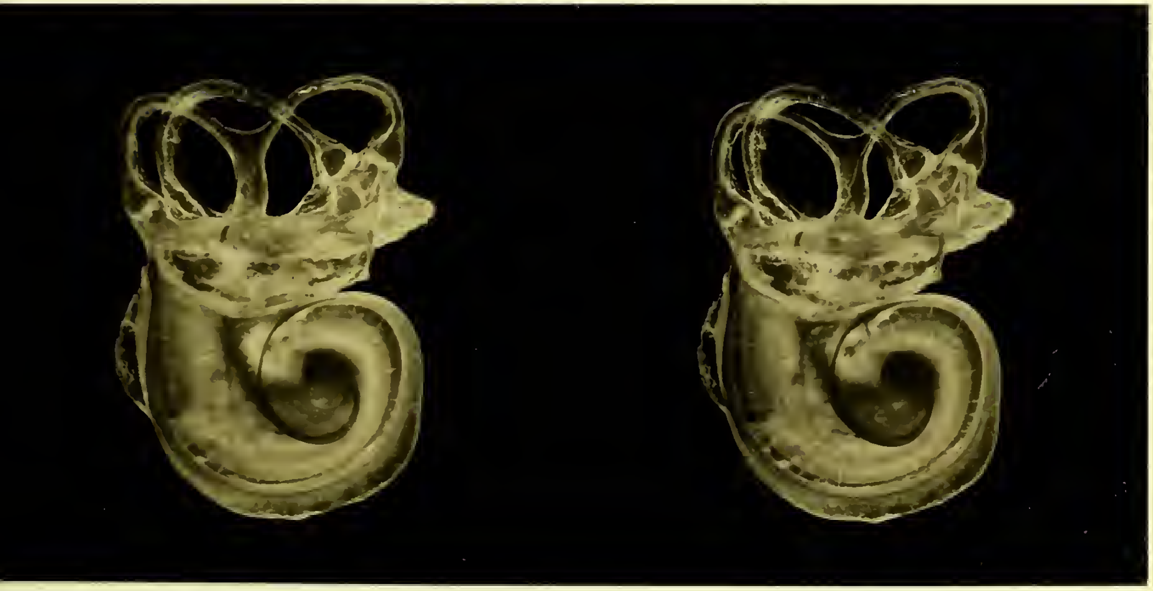


PLATE VIII

THE RIGHT MEMBRANOUS LABYRINTH OF THE DUGONG

Halicore australis

× $3\frac{1}{4}$

The organ is viewed from the inner aspect and in front, and is rotated clock-wise to a considerable extent, so that the horizontal canal is in the vertical plane. The otolith is seen immediately below the ampullæ of the superior and horizontal canals, and the aqueduct of the vestibule is also shown. The lateral view of the cochlea shows very clearly the division between the scala tympani and scala vestibuli.

SIRENIA

THE MEMBRANOUS LABYRINTH OF THE DUGONG

Halicore australis

The labyrinth of this animal is almost as interesting as the animal itself. Although it does not possess the peculiar appearance of the organ as it is found in the cetacea, there are, as has been remarked above, some unique features.

The whole labyrinth measures 18.0 mm. from the outermost point on the posterior canal to the innermost point on the lower whorl of the cochlea. The lower whorl of the *cochlea* has a diameter of 10.5 mm., and the second a diameter of 6.75 mm. The diameter of the tube of the cochlea just in front of the round window is 3.5 mm., and there is no very marked bulging of the floor of the scala tympani in this region such as is found in many mammals. There are one and a half turns in the cochlea, and the slant height of the organ from the upper margin of the round window to the apex is 7.0 mm. The cochlea has a somewhat irregular shape, there being two rounded corners in the lower whorl which detract from the beauty of the organ as compared with those of the majority of the mammalia. It is of the flat type, and, though this is in part due to the fact of there being so few turns, it is not entirely so. The round window is very large, larger indeed than in any other mammal except the whale, and on the under surface of the scala tympani it passes so far inwards that it merges into the aqueduct of the cochlea, a condition not found in any other mammal. For this reason the aqueduct of the cochlea cannot be said in the proper sense of the term to exist as a bony canal. It is as though the bridge of bone, which in all other mammals separates the aqueduct from the round window, had been removed. The aqueduct is therefore represented by an opening in the posterior portion of the round window, through which the perilymph can pass into and out from the scala tympani. The round window is of course closed from the tympanum by a membrane in the usual way. The disposition of the parts is somewhat difficult to describe, but will more easily be understood if the reader will turn to the labyrinth of the sea-lion (vol. i. p. 124). In that animal it will be seen that the round window is rather triangular, and in its lower portion runs for a short distance along the aqueduct. In the sea-cow it is as though this lower part of the round window was drawn out along the whole length of the aqueduct until it met the dura mater. In the sea-cow, however, the tube is so short that it may be said to open immediately into the cranial cavity.

There is a little pigment in the cochlea, found in the usual place along the outer wall of the tube.

The *vestibule* is a broad but shallow cavity measuring 9.0 mm. in its longest diameter, and the oval window is very large, no other animal having it proportionately, and only one, the whale, actually so large. It measures 5.25 mm. in its major axis, and the ellipse is a much narrower one than is commonly the case. Anteriorly the vestibule bulges forward as a conical projection immediately below the opening of the ampullæ of the superior and horizontal canals. This bulging is quite unique among the mammals examined, and is not a mere abnormality in the particular case which is shown in the photograph, since it was found in both labyrinths and was symmetrical on the two sides. But there is yet another peculiarity about this unusual prominence. It will be noticed that the nerves to the superior and horizontal canals actually pass through it and not over it. Now, in all the other mammalian labyrinths examined, it is found to be uniformly the case that the nerves remain outside the cavity of the vestibule until they reach the neuro-epithelium which they are destined to serve, and that then only do they leave the bony canals in which they run. In the dugong, therefore, we find the anomalous condition of a nerve actually running through the perilymph space, and possibly through the endolymph space as well.

The aqueduct of the vestibule is a comparatively thick tube, and may be seen in the photograph. It appears to have a communication with the common limb of the superior and posterior canals, but it is not possible to say if there is any actual opening of sufficient size to allow the endolymph to pass through. The point of contact may be seen in the photograph, and it certainly looks as if there were a true communication between the two channels.

Pigment is found in small quantities on the upper surface of the vestibule between the limbs of the superior canal.

There is one fairly large otolith in the utricle, and it may be seen in the photograph lying in the usual place immediately behind and internal to the ampullæ of the superior and horizontal canals. It is thin and slightly concave, with the concavity directed downwards. A portion of one of the edges is pointed and turns sharply downwards.

The canals of the dugong are small relatively to the rest of the labyrinth ; in the cetacea alone is the disproportion so marked. They are well rounded, and the perilymph space, although not noticeably large, can be traced the whole way round the circumference. Pigment is found in the common limb of the superior and posterior canals, but, curiously, is not found in the ampullæ themselves. One interesting feature is found in the distribution of the nerves to the ampullæ of the superior and horizontal canals. Before reaching the horizontal ampulla, its nerve gives off a twig, which crosses over and joins the nerve to the superior ampulla just as it enters the crista acustica. This condition has not yet been recorded, and it may be of interest to the physiologist. The ampullæ are small relatively to the rest of the canals.

The *superior canal* measures 7.0 mm. in internal, and 8.5 mm. in external diameter. The height of the vertex of the canal above the vestibule is 6.0 mm., and the diameter of the canal itself at the vertex is 0.75 mm. The *posterior canal* has internal and external diameters of 4.75 mm. and 6.75 mm. respectively, and the height of the vertex of the canal above the vestibule is 5.0 mm. The diameter of the canal itself at the vertex is 1.0 mm. The *horizontal canal* measures

5.0 mm. in internal, and 7.0 mm. in external diameter. The height of the vertex of the canal above the vestibule is 5.5 mm., and the diameter of the canal itself at the vertex is 1.0 mm. It is, therefore, to be noted that the posterior is the smallest of the three canals, a relationship which is rare in the mammalia, but in which the sirenia resemble the cetacea.

The nerve-supply to the ampullæ is comparatively scanty when compared with that which is found in many other animals, that is, if one may judge by the thinness of the bundles.

In the vertex of the superior canal, seen in the photograph, there is a deposit of calcareous salts; this is pathological in character.

In general it may be said that the canals and ampullæ of the sea-cow are poorly developed, and this may be associated with the restricted movements of the head upon the trunk. At any rate it may be conjectured that the organs have not such physiological importance in the animal as in the great majority of the mammalia. A somewhat similar degree of development is found in the canals of the sloth, and it is highly suggestive that in the latter the movements are also uncouth.

LITERATURE.—Hyrtl, *Op. cit.* S. 34, 66, &c. Claudius, *Physiolog. Bemerk. über d. Gehör d. Cetaceen u. das Ohr d. Säugeth.* S. 8, 12. Kiel, 1858.

MARSUPIALIA

As may well be understood, the study of the labyrinth of the marsupials is most interesting. The order occupies a peculiar position in regard to the fact that, although its antiquity is known to be very great, yet in its general anatomical structure it presents great resemblances to the other orders of the eutheria ; much closer, for example, than do the monotremes. Fossil remains, which are definitely marsupial, have been found in the Jurassic strata, while definite eutherian remains are not found until the eocene is reached. It should, however, be pointed out that the insectivora may possibly be excepted from this statement, if we are to accept the present insectivora as being descendants of the insectivora primitiva of the Jurassic period.

Remembering, therefore, the comparative antiquity of the order, we should naturally expect to find some sign of antiquity in the labyrinth more marked than is to be found in any other order of the mammalia except the monotremes. In this respect, however, we shall to a certain extent be disappointed, unless further investigations reveal a labyrinth very different from those of the marsupials which have hitherto been examined. It is true that in the marsupial mole the cochlea has only one and a half turns, but the same is true of the hedgehog and the dugong, and in the former of these two animals there is additional evidence of antiquity in the well-developed perilymph space of the canals. With regard also to the peculiar junction of the posterior and horizontal canals at the point at which they cross, which may be considered as additional evidence of antiquity, while it is found in the marsupial mole it is also found in the common mole of Europe. Pigment is not found in the marsupials to any greater extent than in several other orders, and not so much as in some, *e.g.* the rodents. Nor are otoliths more frequently present in the marsupials. The semicircular canals are like those of the ordinary mammalian types, and do not show in any particular way an approach to one more ancient. Indeed, it might almost be said that the canals of the sloth are more primitive in their appearance than those of any of the marsupials, since they are more angular and bear a certain resemblance to those of the monotremes and reptiles.

While, therefore, there is no doubt that the marsupials left the main stem of mammalian descent at a much earlier period than most of the orders, yet, so far as the labyrinth is concerned they have developed along parallel lines to such an extent that the organ must be considered almost as far advanced as in some of these orders. This is particularly true of the diprotodont branch, which presents a labyrinth quite as well developed, if the term may be used, as any of the mammalia. With regard to the polyprotodont division, it may be said that in no case examined is the organ more ancient in appearance than in the insectivora and the sirenia, and it may, perhaps, be added, than in the cetacea. The polyprotodont marsupials have a labyrinth of a distinctly older type than the diprotodonts, and this justifies anatomists in regarding them as of more ancient lineage.

Now, while the appearance of the labyrinth of the marsupials, *as we know them now,* gives us no reason for assuming for recent species a much greater antiquity than can be claimed for some of the other mammalian orders having living representatives, yet we find, in considering the labyrinth of the marsupials as a whole, good evidence for the belief of anatomists (even if no other evidence were obtainable) that the order left the mammalian main stem much earlier than certainly the great majority of the other orders. This evidence lies in the markedly different degrees of development which the organ shows in the species which go to compose the order, and in the variety of types which different parts of the organ present. Thus, as regards the number of turns in the cochlea, we find barely one and a half in the marsupial mole, while in the vulpine phalanger there are no fewer than three and a half, a difference greater than that found in any other order, the heterogeneous one of rodents not excepted.

Further, we have seen that in all the other orders the shape of the cochlea keeps fairly constantly to one type. Thus, in the carnivora the organ is constantly sharp-pointed, so also in the rodents, while in the ungulates and most other orders it is flat. In each order there are of course gradations of type ; as, for example, in the edentata, in which the degree of flatness is different in the sloth and the ant-eater ; and even in the primates there is the peculiar exception of the slow loris. But these differences are not very marked. Now, in the marsupials both types of cochlea are represented, and, what is more remarkable, both types are found in one group of the order. In the wallaby and the kangaroo the cochlea is typically flat, and in the phalanger it is as typically sharp-pointed. In the polyprotodont group the cochlea is of the sharp-pointed type in all the species that have hitherto been examined.

Before leaving this subject it must be impressed on the reader that the remarks here made refer to the marsupials in so far only as the species described, and, while surprise has been expressed that a more ancient type of labyrinth has not been found in the order, it must be pointed out that it is still quite within the bounds of possibility that such a type may yet be met. For example, it might almost be expected in an animal with such primitive features in other respects as the banded ant-eater (*Myrmecobius fasciatus*), or in Cænolestes, the latter being the only species of the diprotodont marsupials found in the American Continent at the present day ; but these the writer has not hitherto had an opportunity of examining.

One other interesting feature to be specially noted is the presence of pigment, which is found in the same situations as in the other orders of the mammalia. It is more abundant in the polyprotodonts than in the diprotodonts. In the ampullæ of the canals it is distributed in the form of a crescent, similarly to its disposition in the other orders of mammals, but not in quite so regular a pattern as in some. In none of the species examined by the writer was the pigment so abundant as in the capybara or the jerboa.

Otoliths sufficiently large to be recognised by the naked eye have only been found in the wallaby, and even in this case the writer may have been in error, although the crystals were found to be symmetrical on both sides.

The aqueduct of the cochlea in the marsupials varies within wide limits. In the kangaroo and wallaby it is a wide tube, in the phalanger it is much narrower, while in all the polyprotodonts which have been examined it is so fine as to break in the process of preparation. The aqueduct of the vestibule is always fine, but in some cases it can be preserved.

The examples of the marsupials which the writer has had the opportunity of examining are, of the diprotodonts—the kangaroo, the wallaby, and the phalanger; and of the polyprotodonts—the marsupial mole, the pouched jerboa mouse, the bandicoot, the pouched mouse, and the brush-tailed phascologale.

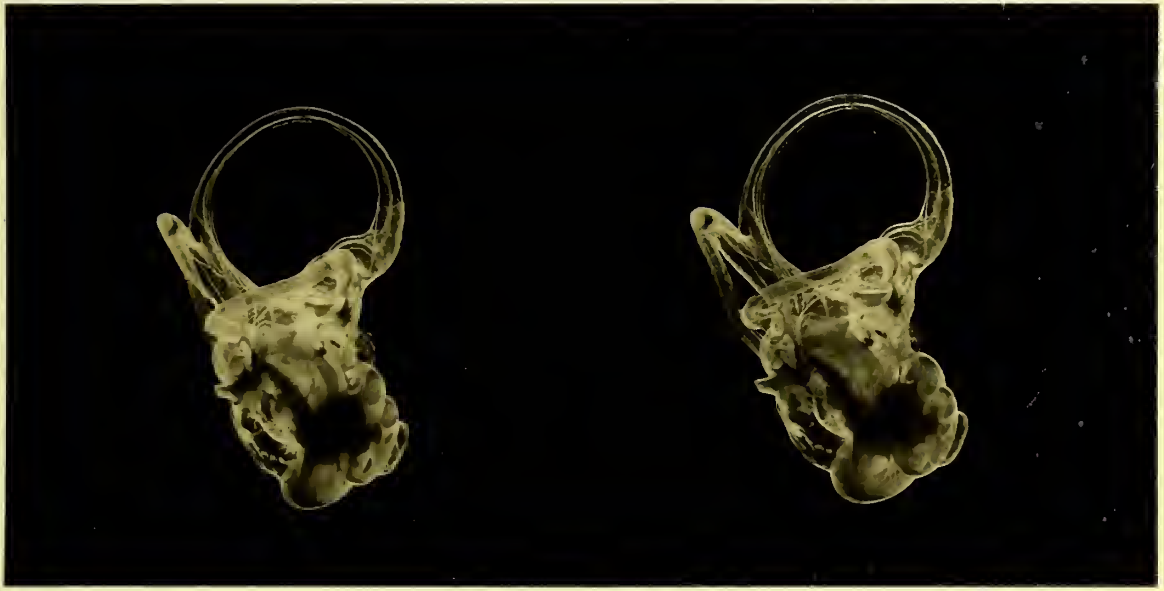
PLATE IX

THE RIGHT MEMBRANOUS LABYRINTH OF THE BRUSH-TAILED WALLABY

Petrogale penicillata

× 6

The organ is suspended by the superior canal and is viewed from the outer aspect. One of the otoliths is seen below and internal to the ampullæ of the superior and horizontal canals. The oval and round windows are shown, and it will be seen that the latter stretches backwards towards the aqueduct of the cochlea. The cochlea is of the flat type.



MARSUPIALIA

THE MEMBRANOUS LABYRINTH OF THE BRUSH-TAILED WALLABY

Petrogale penicillata

In the wallaby, as also in the kangaroo, the cochlea is of the flat type, being somewhat similar to that of the ungulates.

The whole organ measures 8.0 mm. from the outermost point on the vertex of the posterior canal to the innermost point on the lowest whorl of the cochlea. The diameter of the lowest whorl of the *cochlea* is rather less than 4.5 mm., while that of the second is 2.5 mm. There is a marked bulging of the floor of the scala tympani in the region of the aqueduct, and the tube of the cochlea at this point measures 2.5 mm. in diameter. There are nearly three turns in the cochlea, and the slant height of the organ from the apex to the upper margin of the round window is 3.75 mm. The aqueduct of the cochlea is short and thick, measuring about 1.5 mm. in length. It is not triangular, as in most mammals, but is flattened from above downwards.

In proportion to the rest of the labyrinth the *vestibule* is rather large, measuring 4.0 mm. in its longest diameter. The major axis of the oval window is rather more than 1.5 mm. in length. Two otoliths of considerable size are found in the vestibule, one lying immediately behind the ampullæ of the superior and horizontal canals, and the other a little below it. Both are flat and irregular in shape.

The semicircular canals are similar to those of other mammals, and are beautifully regular in outline, reminding one of the same structures in the antelope, though, of course, they are much smaller. The *superior canal* measures 3.5 mm. in internal, and 5.0 mm. in external diameter. The height of the vertex of the canal above the vestibule is 3.0 mm., and the diameter of the canal itself at the vertex is 0.5 mm. The internal diameter of the *posterior canal* is 3.0 mm. and the external diameter is 4.5 mm. The height of the vertex above the vestibule is 3.0 mm., and the diameter of the canal itself at the vertex is 0.5 mm. Thus the posterior canal is smaller than the superior. The smallest of the three is the *horizontal canal*, which measures 3.0 mm. in internal, and 4.0 mm. in external diameter. The height of the vertex above the vestibule is 2.75 mm., and the diameter of the canal itself at the vertex is 0.5 mm.

The perilymph space in the canals is very small, and, as is always the case, it is largest in the angles formed by the ampullæ with the canals themselves.

A little pigment is present in the ampullæ.

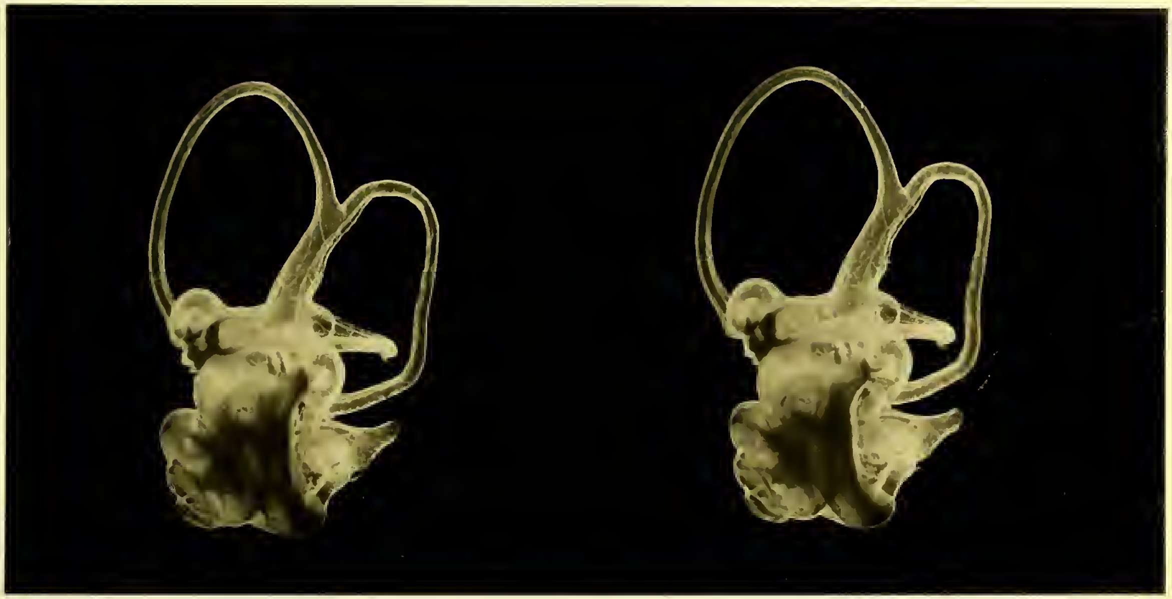
PLATE X

THE LEFT MEMBRANOUS LABYRINTH OF THE BLACK-FACED KANGAROO

Macropus melanops

× 5

The organ is suspended by the superior canal and is viewed from the outer aspect and in front. The cochlear portion is very similar to that of the wallaby. The canals are not so regular in shape, and there is pigment present in the ampullæ. An ampulla-like dilatation is seen in the posterior extremity of the horizontal canal, but there is no nerve supply to this. It is comparable to the ampulla sometimes found in the same position in the human subject. (*Vide* Gray, *Journ. of Anat. and Physiolog.* vol. xxxix. p. 349.)



MARSUPIALIA

THE MEMBRANOUS LABYRINTH OF THE BLACK-FACED KANGAROO

Macropus melanops

As would be expected from the close relationship which exists between the wallaby and the kangaroo, the labyrinths of the two animals are very similar. The most noticeable difference is in the canals, which are very regularly curved in the wallaby, and with less regularity in the kangaroo. Pigment is greater in amount in the kangaroo, and the number of turns in the cochlea is nearly three in the wallaby, while it is two and three quarters in the kangaroo.

The whole organ measures 12.0 mm. in length from the outermost point on the posterior canal to the innermost point on the lowest whorl of the cochlea. The lowest whorl of the *cochlea* has a diameter of 6.0 mm., and the second a diameter of rather less than 3.5 mm. The diameter of the tube of the cochlea just in front of the round window is rather more than 3.5 mm. There is a marked bulging[1] of the floor of the scala tympani in this region, and the aqueduct of the cochlea is wide, gradually tapering off from the floor of the scala tympani, as seen in the photograph. The slant height of the organ measured from the upper margin of the round window to the apex is 4.75 mm. Pigment is found in considerable quantity along the outer wall of the cochlea in the lowest whorl. The cochlea has two and three quarter turns, and is of the flat type.

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[1] In regard to the interesting phylogenetic significance of this bulging, see p. 108.

The *vestibule* measures 4.0 mm. in its longest diameter, and the major axis of the oval window 2.0 mm. There are a few otoliths in the vestibule of a size just sufficient to be recognised by the naked eye, and no pigment. The aqueduct of the vestibule, though a fine tube, is not quite so delicate as in the majority of mammals, and can be preserved in the process of preparation. It may be seen in the photograph behind the point at which the common limb of the superior and posterior canals leaves the vestibule.

The canals are relatively rather large, but are very thin and delicate in proportion to their length. The superior is the largest and the horizontal the smallest of the three, a relationship which is the usual one in mammals, but which is more decided in the present instance than in most animals. The *superior canal* measures 5.75 mm. in internal, and rather more than 6.75 mm. in external diameter. The height of the vertex of the canal above the vestibule is 6.0 mm., and the diameter of the canal itself at the vertex is 0.5 mm. The *posterior canal* has internal and external diameters of 4.5 mm. and 6.5 mm. respectively, the height of the vertex of the canal above the vestibule is 5.35 mm., and the diameter of the canal itself at the vertex is 0.5 mm. The *horizontal canal* measures 4.0 mm. in internal, and 5.0 mm. in external diameter. The height of the vertex of the canal above the vestibule is 3.75 mm., and the diameter of the canal itself at the vertex is 0.5 mm. The superior and posterior canals are rather more elliptical in shape than those of the wallaby or the phalanger. In the canals of the kangaroo the perilymph space is very much reduced, more so than in the wallaby, or even than in the phalanger.

The ampullæ of the canals contain a fair quantity of pigment, but it is not deposited so regularly in the form of a crescent as in many of the mammalia.

The oval window is somewhat broader in its anterior than posterior portion. The round window is pear-shaped, the pointed end being directed a little way along the aqueduct of the cochlea, as in the sea-lion and wallaby.

LITERATURE.—Hyrtl, *Op. cit.* S. 24. Denker, *Op. cit.* S. 64.

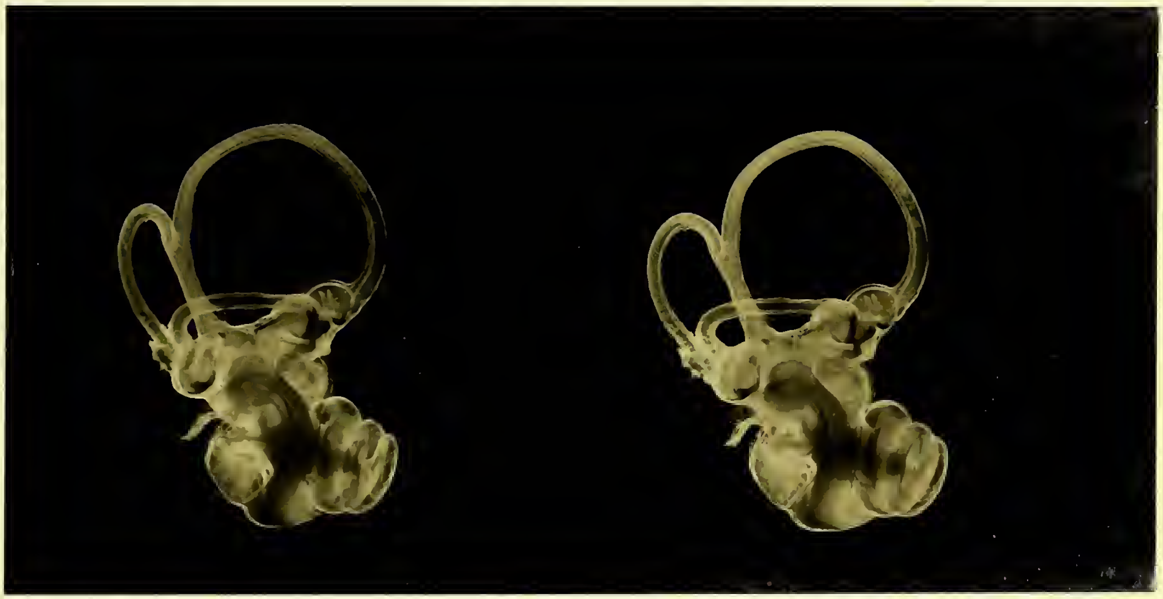
PLATE XI

THE RIGHT MEMBRANOUS LABYRINTH OF THE VULPINE PHALANGER

Trichosurus vulpecula

× 6

The organ is suspended by the superior canal and is viewed from the outer aspect. A little pigment is present in the ampullæ of the canals. The posterior limb of the horizontal canal is fused with the inferior limb of the posterior canal. In the ampulla of the superior canal the cilia are arranged in two transverse rows. The oval window is quite different in shape from that of the kangaroo, and the cochlea is distinctly of the sharp-pointed type.



MARSUPIALIA

THE MEMBRANOUS LABYRINTH OF THE VULPINE PHALANGER

Trichosurus vulpecula

Although the phalanger belongs to the diprotodont group of the marsupials, the labyrinth is in one respect very different from those of the kangaroos and wallabies. In the two latter, which belong to the family of the macropodidæ, the cochlea is distinctly of the flat type, while in the phalangeridæ it is markedly sharp-pointed.

The labyrinth of the phalanger measures 9.0 mm. in its greatest length from the outermost point on the vertex of the posterior canal to the innermost point on the lowest whorl of the cochlea. The diameter of the lowest whorl of the *cochlea* is 4.0 mm., while that of the second is 2.75 mm. in length. The diameter of the tube of the cochlea just in front of the round window is 2.5 mm., this relatively large measurement being due to the fact that the floor of the scala tympani bulges downwards in the region of the aqueduct of the cochlea.

The *vestibule* measures rather more than 2.75 mm. in its longest diameter, and there are no otoliths of a size sufficient to be recognised by the naked eye. The major axis of the oval window has a length of nearly 1.5 mm.

The *superior canal*, which is by far the longest of the three, has an internal diameter of 4.5 mm., and an external diameter of 5.25 mm. The height of the vertex of the canal above the vestibule is 4.25 mm., and the diameter of the canal itself at the vertex is 0.5 mm. The *posterior canal* measures 3.0 mm. in its internal, and a little less than 4.0 mm. in its external diameter. The height of the vertex of the canal above the vestibule is 3.0 mm., and the diameter of the canal itself at the vertex is 0.5 mm. The internal diameter of the *horizontal canal* is 2.5 mm., and the external diameter of the same canal is rather less than 3.5 mm. The height of the vertex of the canal above the vestibule is 2.5 mm., and the diameter of the canal itself at the vertex is 0.5 mm.

The cochlea has three and a quarter turns, and the slant height of the organ, measured from the upper margin of the round window to the apex, is not quite 4.0 mm.

Pigment is present in the labyrinth of the phalanger to a limited extent. It is found in the ampullæ of all the canals. There are in each ampulla two patches of pigment, one of which lies between the entrance of the nerve and the opening into the vestibule, and the other between the entrance of the nerve and the canal proper. The arrangement is thus the same as in other mammals. The crista acustica of the ampulla presents a rather peculiar appearance. The long hairs which run from the cells of the crista appear to be arranged in two parallel rows running transversely across the ampulla. The hairs seem to be of great size, and almost reach the inner wall of the ampulla. They are seen very clearly in the ampulla of the superior canal in the photograph.

The perilymph space is very small in the canals of the phalanger, the animal being in this respect like the kangaroos.

In general it may be said that the canals of the phalangers are very similar to those of the kangaroos, while the cochlea is very different. The cochlea of the phalangers is almost identical in appearance with that of carnivora, such as the canidæ, while, in the kangaroos and wallabies, it is more like that of the ungulates. The posterior limb of the horizontal canal opens into the ampulla of the posterior canal, a condition not, however, very uncommon in the mammalia.

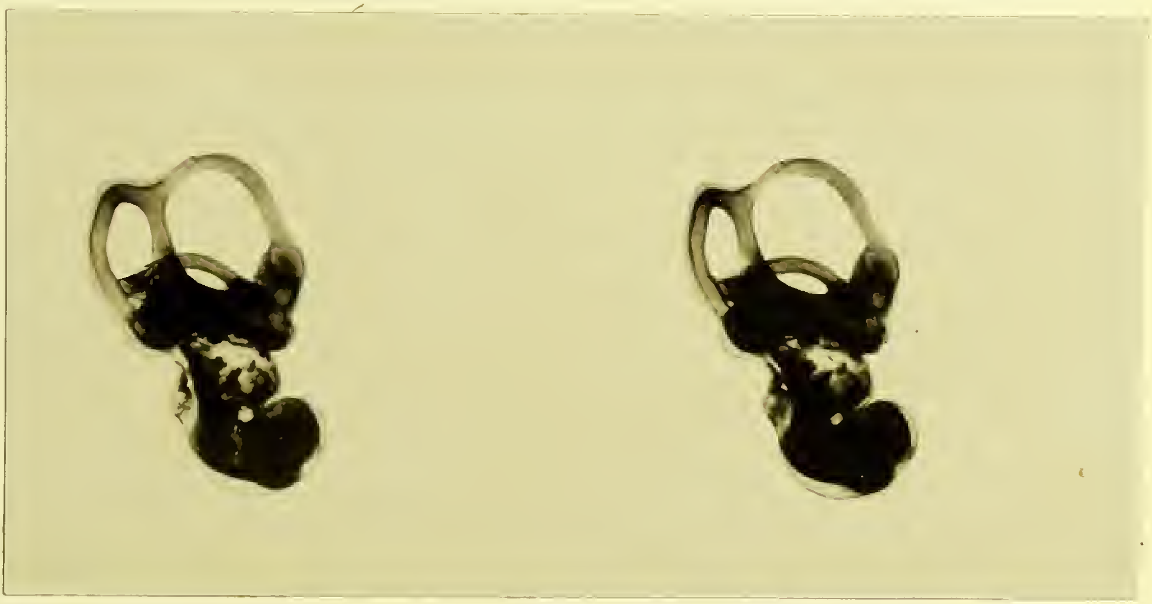
PLATE XII

THE RIGHT MEMBRANOUS LABYRINTH OF THE MARSUPIAL MOLE

Notoryctes typhlops

× 10

The specimen is a very poor one, owing to the drying of the preparation. The canals are relatively thick, and there is a channel of communication between the horizontal and posterior canals, a very rare condition in the mammalia but a common one in the birds and reptiles. The cochlea has less than one and a half turns, and is obviously of the sharp-pointed type.



MARSUPIALIA

THE MEMBRANOUS LABYRINTH OF THE MARSUPIAL MOLE

Notoryctes typhlops

The marsupial mole possesses the most ancient type of labyrinth of all the examples of this order which the writer has as yet had an opportunity of examining. Most unfortunately the specimen had become somewhat dried before it reached the writer, with the result that the membranous structures of the labyrinth had collapsed, and do not show the detail which should be found in good specimens. This accounts for the poor appearance of the photograph, and for the double outline which is to be seen over nearly the whole organ, since, the membranous structures having collapsed, the celloidin in which the preparations are placed during the process of embedding, has penetrated between the bone and the membranous tissues. Again, the deposits which may be seen in all parts of the labyrinth in the photograph are not pigment, for which they might be mistaken, but are opacities resulting from the drying up of some of the albuminoid substances. In spite of these defects, however, the labyrinth of this animal is of such importance that it is desirable to show the appearance of even a poor specimen.

The whole organ measures 4.5 mm. from the outermost point on the vertex of the posterior canal to the innermost point on the lowest whorl of the cochlea. The diameter of the lowest whorl of the *cochlea* is 2.0 mm., and that of the second 1.25 mm. The diameter of the tube of the cochlea just in front of the round window is rather more than 0.75 mm., and the slant height of the organ from the upper margin of the round window to the apex is 1.25 mm. The organ possesses only one and a half turns, and is of the sharp-pointed type. In this latter respect it agrees with the other species of polyprotodonts. Owing to the faulty nature of the specimen it is impossible to say whether or not pigment is present in the cochlea.

The *vestibule* measures rather more than 1.5 mm. in its longest diameter, and the major axis of the oval window 0.5 mm. It is impossible to say whether there are otoliths in the vestibule of a size sufficient to be seen by the naked eye, and the same remark applies to the presence or absence of pigment. The aqueduct of the vestibule is very fine and breaks in the process of preparation.

The canals are not very fine, and their curvature is not very regular. Neither is there any very great disproportion in the lengths of the canals. The *superior canal* measures 1.75 mm. in internal, and 2.5 mm. in external diameter. The height of the vertex of the canal above the vestibule is 1.75 mm., and the diameter of the canal itself at the vertex is rather more than 0.25 mm. The *posterior canal* has internal and external diameters of 1.25 mm. and 2.0 mm. respectively. The height of the vertex above the vestibule is rather more than 1.5 mm., and the diameter of the canal itself at the vertex is rather more than 0.25 mm. The *horizontal canal* measures 1.25 mm. in internal, and 2.0 mm. in external diameter. The height of the vertex above the vestibule is rather more than 1.0 mm., and the diameter of the canal itself at the vertex is a little more than 0.25 mm.

The ampullæ of the canals of the marsupial mole are not large in proportion to the rest of the canal, a feature in which this labyrinth is in contrast with those of all the other marsupials that have been examined. Perhaps, however, the most interesting feature of the canals of the marsupial mole is the junction between the posterior and horizontal canals at the point at which the latter passes under the former. This condition, which can be seen in the photograph, must not be confounded with the not uncommon one in which the horizontal canal at its posterior extremity opens into the ampulla of the posterior. The junction takes place in the canals proper, and is quite like that which is usually seen in the canals of birds. In mammals it is extremely rare; indeed, the writer has only found it definitely present in three others—the common mole, the phascologale, and the pouched jerboa mouse; it is possibly present also in the dromedary, but in this last case it may have been an abnormality. It is an interesting link between the marsupial and the common mole, for, although they belong to quite different orders, these are both ancient, and the condition is possibly a vestige of reptilian ancestry, since, as will be seen later, this commissure is commonly present in the reptiles as well as in the birds.

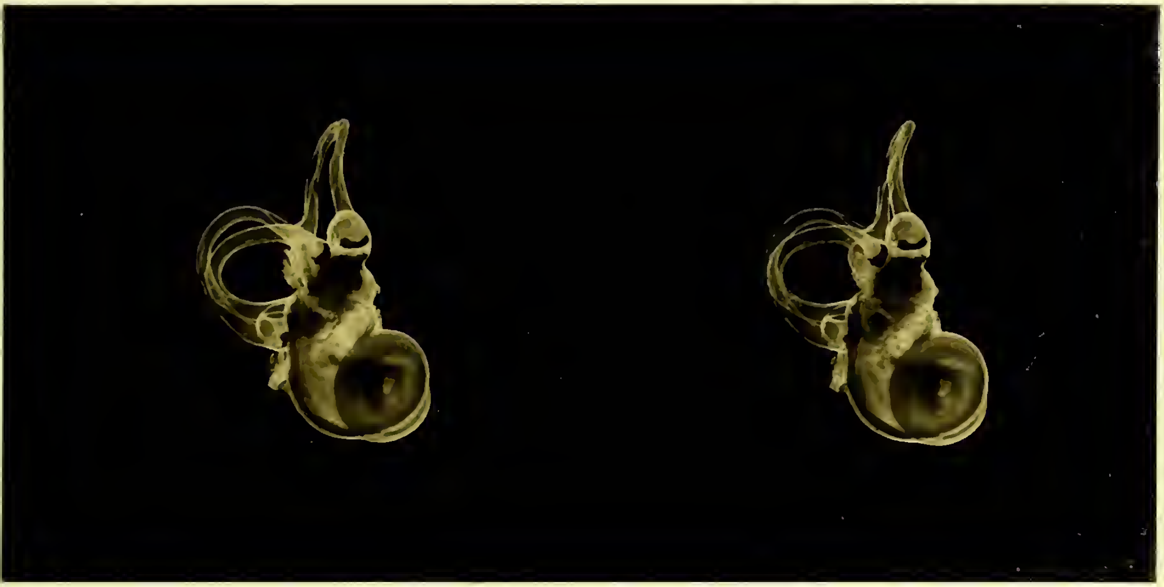
PLATE XIII

THE RIGHT MEMBRANOUS LABYRINTH OF THE POUCHED JERBOA MOUSE

Antechinomys lanigera

× 9½

The organ is suspended by the superior canal and is viewed from in front and below. The canals are thick, but the perilymph space is hardly present. There is a communication between the horizontal and posterior canals. The ampullæ are large, and there is a rich deposit of pigment in them and in the vestibule. The cochlea contains one and three quarter turns, and there is a broad band of pigment in the region of the spiral ligament. The cochlea is of the sharp-pointed type.



MARSUPIALIA

THE MEMBRANOUS LABYRINTH OF THE POUCHED JERBOA MOUSE

Antechinomys lanigera

The labyrinth of this rare marsupial, although interesting, does not show evidence of such great antiquity as does that of the marsupial mole which has just been described. It is clearly more ancient in type than those of the diprotodont group of marsupials.

The whole organ is of almost exactly the same size as that of the marsupial mole, measuring 4.5 mm. from the outermost point on the vertex of the posterior canal to the innermost point on the lower whorl of the cochlea. The diameter of the lower whorl of the *cochlea* is 2.0 mm., and that of the second 1.5 mm.; hence the organ is very definitely of the sharp-pointed type. There are one and three quarter turns in the cochlea, and there is a well-marked and broad band of pigment along the outer wall of the cochlear tube; this band of pigment becomes fainter towards the apex of the cochlea, as is usually the case in the mammalia. The tube of the cochlea just in front of the round window is 1.0 mm. in diameter, and the slant height of the organ measured from the upper margin of the round window to the apex, is 1.75 mm.

The aqueduct of the cochlea is a very fine tube, and breaks in the process of preparation. There is a fairly well-marked bulging of the floor of the scala tympani in the region of the opening of the aqueduct of the cochlea.

The *vestibule* measures 2.0 mm. in its longest diameter, and the oval window has a major axis of 0.5 mm. As in other marsupials, the oval window is not so markedly elliptical in shape as in most of the mammalian orders. There is a considerable amount of black pigment in the vestibule, and as is commonly found, this is almost if not entirely confined to the utricle. The aqueduct of the vestibule is proportionately much thicker than is usually the case, and can be preserved in the process of preparation ; it may be seen in the photograph behind the common limb of the posterior and superior canals.

The canals of the animal are well curved and rather thick in proportion to their length. This is the more remarkable in view of the fact that the perilymph space is not present in at all the same degree as is common in labyrinths with canals of large calibre. The ampullæ are large and spherical, in which respect they differ from those of the marsupial mole. Pigment is found in each of the ampullæ, and the deposit is of much the same shape as in the other mammals in which it is present in this locality. That is to say, it is arranged crescentically in the convex portion of the ampulla, and distal to the crista acustica. Another patch of pigment is present in each of the ampullæ in the part which is proximal to the crista, but this deposit is in direct continuity with that found on the upper surface of the vestibule. In fact the deposit is very similar in its arrangement to that which is found in the capybara. A somewhat fainter streak of pigment runs from the vestibule up the anterior surface of the common limb of the posterior and superior canals.

The *superior canal* measures 2.25 mm. in internal, and 2.75 mm. in external diameter. The height of the vertex above the vestibule is 2.25 mm., and the diameter of the canal itself at the vertex is 0.25 mm. The *posterior canal* measures 1.75 mm. in internal, and 2.25 mm. in external diameter. The height of the vertex above the vestibule is 1.75 mm., and the diameter of the canal itself at the vertex is 0.25 mm. The *horizontal canal* has an internal diameter of 1.5 mm. and an external of 2.0 mm. The height of the vertex above the vestibule is 1.5 mm., and the diameter of the canal itself at the vertex is 0.25 mm. Thus the superior is the largest of the three canals and the horizontal the smallest, a relationship which is that most commonly found in the mammalia.

MARSUPIALIA

THE MEMBRANOUS LABYRINTH OF THE POUCHED MOUSE

Sminthopsis larapinta

This small marsupial belongs to the same family as antechinomys and phascologale, and the appearance of the labyrinth, though smaller, is very similar. The specimen was unfortunately rather dry when the writer received it, consequently the labyrinth does not make a very good preparation; and, owing to the opacity of the organ, it has not been possible to obtain a satisfactory photograph. In the following description, therefore, only the appearance of the outline is given, along with the actual measurements.

The organ measures 4.0 mm. in extreme length from the outermost point on the posterior canal to the innermost point on the lowest whorl of the cochlea. The diameter of the lowest whorl of the *cochlea* is 2.0 mm. and that of the second 1.25 mm. The diameter of the tube of the cochlea just in front of the round window is 1.0 mm., and the slant height from the upper margin of the round window to the apex is 1.5 mm. The organ is distinctly of the sharp-pointed type. The aqueduct of the cochlea is a very fine tube, and breaks in the process of preparation. There are one and three quarter turns in the cochlea.

The *vestibule* measures 1.75 mm. in its longest diameter, and the major axis of the oval window has a length of rather less than 0.5 mm.

The *superior canal* has an internal diameter of 1.5 mm. and an external of 2.25 mm. The height of the vertex of the canal above the vestibule is 1.5 mm., and the diameter of the canal itself at the vertex is rather less than 0.25 mm. The *posterior canal* measures 1.0 mm. in internal, and 1.75 mm. in external diameter. The height of the vertex above the vestibule is 1.25 mm., and the diameter of the canal itself at the vertex is rather less than 0.25 mm. The *horizontal canal* has internal and external diameters of 1.0 mm. and 1.5 mm. respectively. The height of the vertex above the vestibule is 1.25 mm., and the diameter of the canal itself at the vertex is rather less than 0.25 mm. The canals are well rounded, and are very similar in appearance to those of antechinomys. There is a crescentic deposit of pigment in the ampullæ, but it is not possible to state definitely from the specimen whether or not it is regular in outline. The opacity of the specimen also renders it impossible to ascertain whether the perilymph space is present in the canals at all, and if so, to what extent.

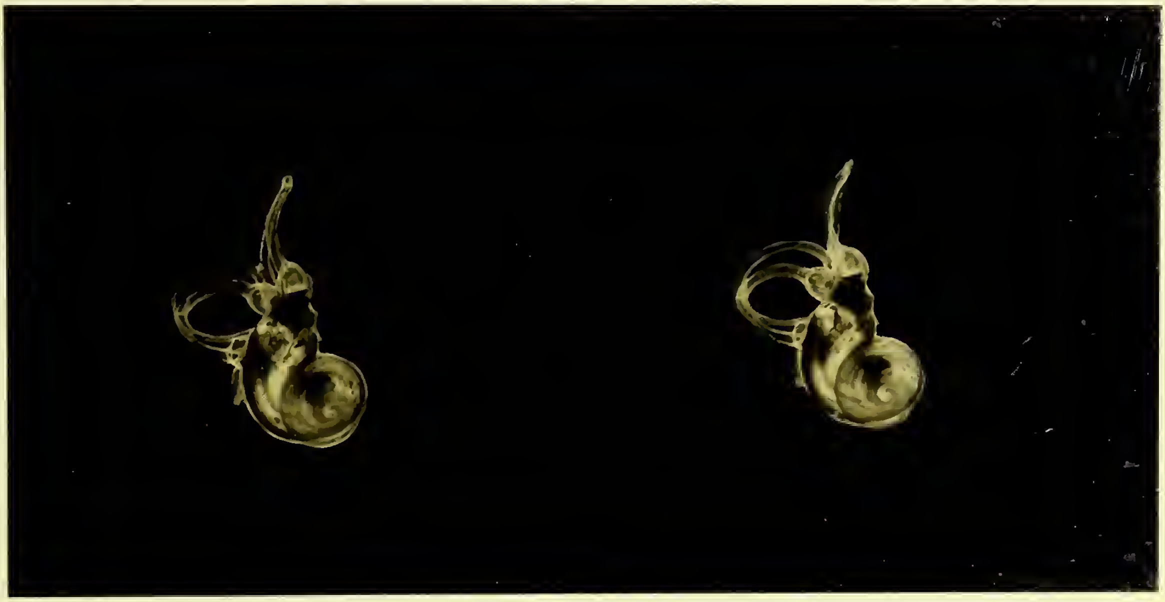
PLATE XIV

THE RIGHT MEMBRANOUS LABYRINTH OF THE BRUSH-TAILED PHASCOLOGALE

Phascologale penicillata

× 6

The organ is suspended by the superior canal and is viewed from in front and below. The canals are regularly curved, and the perilymph space is almost absent. There is a channel of communication between the horizontal and posterior canals. Pigment is present in the ampullæ and on the upper surface of the vestibule. There is a faint deposit of pigment in the region of the spiral ligament. The cochlea has two and a half turns.



MARSUPIALIA

THE MEMBRANOUS LABYRINTH OF THE BRUSH-TAILED PHASCOLOGALE

Phascologale penicillata

The phascologale belongs to the same family as the two animals immediately preceding, and its labyrinth resembles theirs, but is a little larger.

The whole organ measures 5.75 mm. from the outermost point on the vertex of the posterior canal to the innermost point on the lowest whorl of the cochlea. The diameter of the lowest whorl of the *cochlea* has a length of 3.0 mm., and that of the second 2.0 mm. The diameter of the tube of the cochlea just in front of the round window is 1.5 mm., and there is a bulging of the floor of the scala tympani in the region of the aqueduct of the cochlea similar to that found in the other two members of the family which have been described. The slant height of the cochlea from the apex to the upper margin of the round window is 2.5 mm., and the organ is distinctly of the sharp-pointed type. There is a band of pigment along the outer side in the region of the stria vascularis similar to that found in other mammals, and, as is always the case, it is more marked in the lowest whorl. There are two and a half turns in the cochlea.

The *vestibule* measures 2.5 mm. in its longest diameter, and the major axis of the oval window has a length of rather less than 1.0 mm. The aperture of the oval window is a fairly regular ellipse. Owing to the presence of pigment in the vestibule it is impossible to say that otoliths are absent, but none are to be seen in the photograph. The pigment is present in the form of a black irregular mass in the utricle, none being found in the saccule.

The canals are well-rounded : the superior one does not, like its companions, lie in one plane, but has a well-marked inclination inwards at the vertex. The perilymph space is very small, but is present in all the canals, and with care may be traced throughout their course. The ampullæ are all fairly large in proportion to the size of the labyrinth, and are roughly spherical, being in this respect in contrast with those of the marsupial mole. One feature the labyrinth has in common with that of the last-named animal : there is a communication between the perilymph spaces of the posterior and horizontal canals. It will be remembered that this condition is also found in the common mole and some polyprotodont marsupials, but is not found in the diprotodont branch of the order. Pigment is found in all the ampullæ, but is very scanty in that of the horizontal canal. In the superior canal the pigment is distributed in the form of a shallow crescent in the distal portion of the ampulla ; in the proximal portion it is not so definitely crescentic, and is continuous with the rich deposit which is found in the upper wall of the vestibule.

The *superior canal* measures 2.5 mm. in internal, and

3.25 mm. in external diameter. The height of the vertex above the vestibule is 3.0 mm., and the diameter of the canal itself at the vertex is rather less than 0.5 mm. The internal and external diameters of the *posterior canal* are rather less than 2.0 mm. and 3.0 mm. respectively. The height of the vertex above the vestibule is 2.25 mm., and the diameter of the canal itself at the vertex is rather less than 0.5 mm. The *horizontal canal* measures 2.0 mm. in internal, and 3.0 mm. in external diameter. The height of the vertex above the vestibule is 2.0 mm., and the diameter of the canal itself at the vertex is rather less than 0.5 mm. Thus the superior is the longest of the canals, while the horizontal and posterior are of almost equal size.

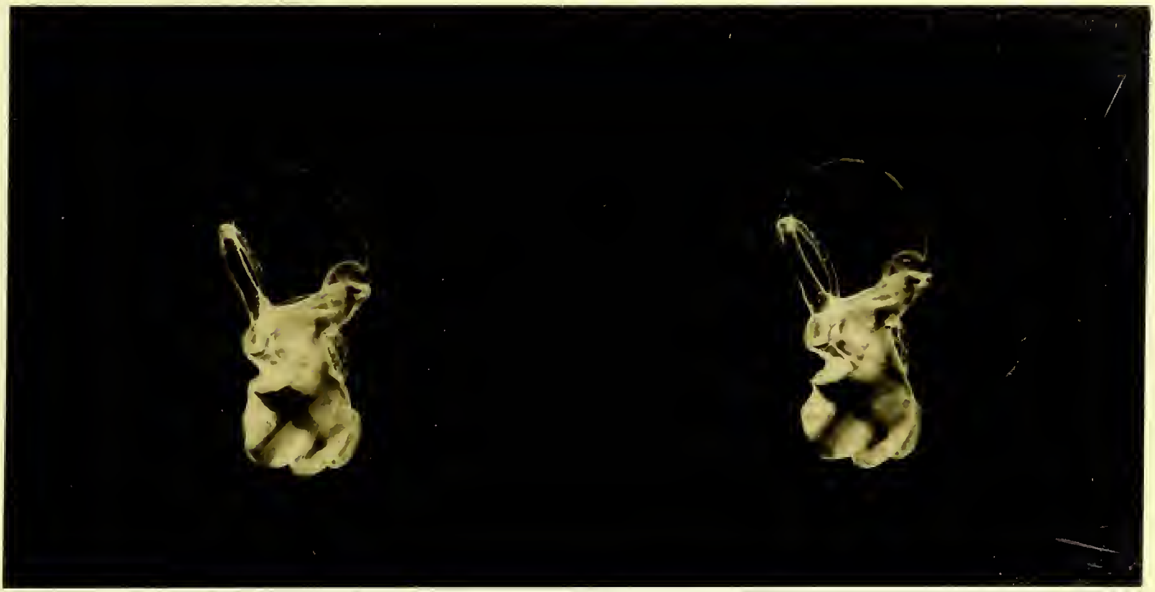
PLATE XV

THE LEFT MEMBRANOUS LABYRINTH OF THE SHORT-NOSED BANDICOOT

Perameles obesula

× 6¾

The organ is suspended by the superior canal and is viewed from the inner aspect. The canals are regularly curved, and the perilymph space is not well-developed. The cilia in the ampullæ are arranged in two transverse rows similar to the condition found in the phalanger, but the two rows are not of equal height. Two crescentic deposits of pigment are seen in the ampullæ, one on each side of the crista acustica, and are similar to those found in many other mammals. Two otoliths are present in the vestibule, one in the utricle and the other in the saccule. The cochlea is of the sharp-pointed type, and contains two and a quarter turns.



MARSUPIALIA

THE MEMBRANOUS LABYRINTH OF THE SHORT-NOSED BANDICOOT

Perameles obesula

If we were to judge by the appearance of the labyrinth alone, the short-nosed bandicoot would be one of the most highly developed of the polyprotodont marsupials yet examined. The cochlea has two and a quarter turns, this being the largest number which has as yet been found in the polyprotodonts, with the exception of the phascologale.

The whole organ measures 6.5 mm. from the outermost point on the vertex of the posterior canal to the innermost point on the lowest whorl of the cochlea. The lowest whorl of the *cochlea* measures 3.0 mm. and the second 2.0 mm. in diameter. The diameter of the tube of the cochlea just in front of the round window is 1.75 mm., and there is a considerable bulging of the floor of the scala tympani in this region. The aqueduct is a very fine tube, and breaks in the process of preparation. The slant height, measured from the upper margin of the round window to the apex, is 2.75 mm., and the organ is very distinctly of the sharp-pointed type. A faint band of pigment is found along the outer wall, but in the upper turns it is barely visible.

The *vestibule* has a maximum diameter of 2.25 mm., and the oval window measures 1.0 mm. in its major axis. Pigment is present in the vestibule in minute quantities only. The aqueduct of the vestibule is a very fine tube, and breaks in the process of preparation. No otoliths of a size sufficient to be recognised by the naked eye are found in the vestibule.

The canals are of moderate dimension, are well rounded, and proportionately thinner than in the pouched jerboa mouse or the marsupial mole. The perilymph space is very faintly seen in the canals, and indeed is absent along a large part of their course. The *superior canal* measures 3.0 mm. in internal, and 4.0 mm. in external diameter. The height of the vertex above the vestibule is 3.0 mm., and the diameter of the canal itself at the vertex is 0.25 mm. The *posterior canal* has internal and external diameters of 2.0 mm. and 3.0 mm. respectively, and the height of the vertex above the vestibule is 2.25 mm. The canal itself has a diameter at the vertex of rather more than 0.25 mm. The *horizontal canal* measures 2.0 mm. in internal, and 3.0 mm. in external diameter. The height of the vertex above the vestibule is rather less than 2.0 mm., and the diameter of the canal itself at the vertex is rather more than 0.25 mm.

Pigment is present in the ampullæ of the canals, disposed in very much the same way as in the polyprotodont marsupials already described, but in much smaller quantities. That is to say, there are in each ampulla two crescentic deposits, one on the proximal and one on the distal side of the crista acustica.

An interesting feature may be seen in the ampullæ of the bandicoot. In the crista two rows of cilia run transversely, in a manner similar to that seen in the vulpine phalanger. In the latter animal, however, the rows of cilia appear to be of nearly equal height, while in the bandicoot the row nearer the vestibule is distinctly the higher, and indeed almost divides the ampulla into two portions, one adjacent to the vestibule and the other to the canal proper. The distal row of cilia is only about half the height of the proximal. These features may be seen in the ampulla of the superior canal in the photograph.

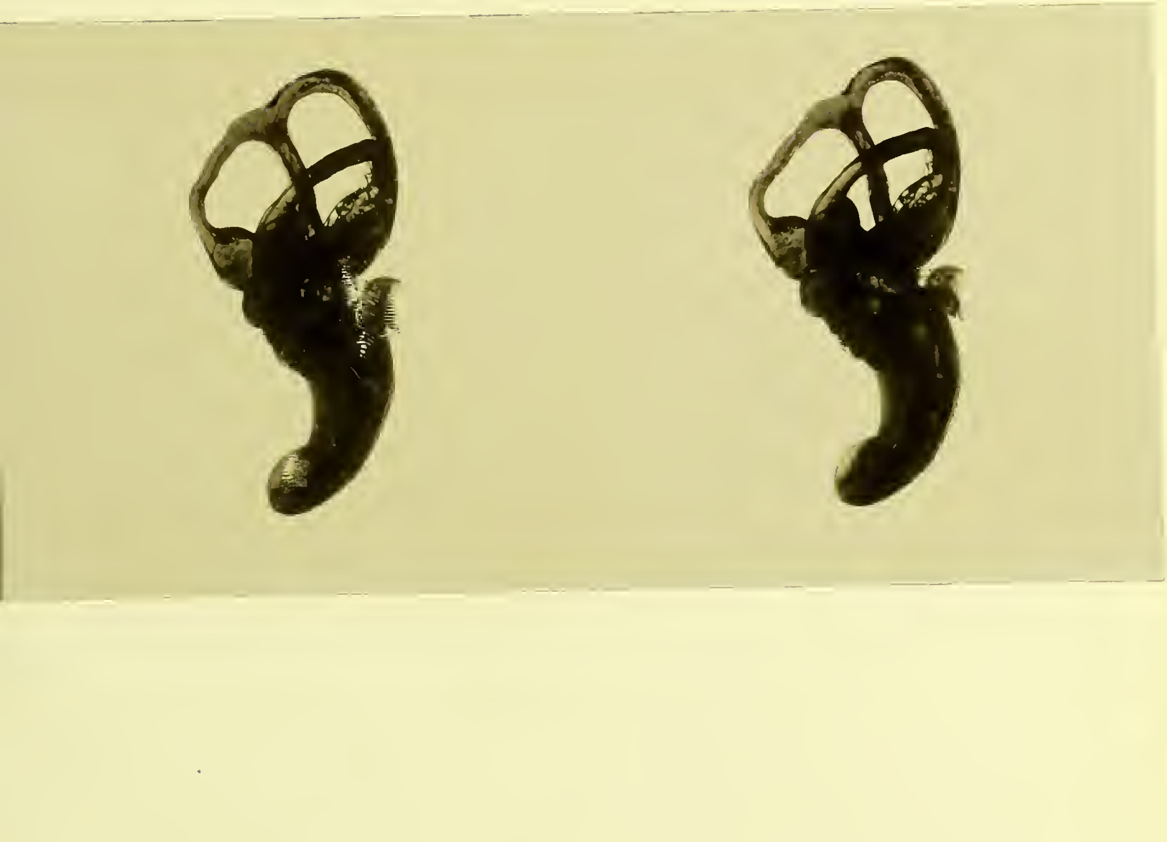
PLATE XVI

THE LEFT MEMBRANOUS LABYRINTH OF THE DUCK-BILLED PLATYPUS

Ornithorhyncus anatinus

× 5½

The organ is suspended by the posterior canal and is viewed from in front, below and outside. It is also rotated a little counter-clockwise. The specimen is a poor one owing to the hæmorrhages which have occurred throughout the whole organ. The cochlea only possesses half a turn, and is not unlike those found in birds and some reptiles. The superior canal, which is to the left, is angular, and suggestive of the reptilian type; but the vestibule is not so large as in the latter. The aqueduct of the cochlea is seen to the right side of the organ as it leaves the vestibule.



MONOTREMATA

THE MEMBRANOUS LABYRINTH OF THE DUCK-BILLED PLATYPUS

Ornithorhyncus anatinus

As might have been expected, the labyrinth of the platypus is very different from that of any other mammal. In appearance it may be said to stand midway between the labyrinth of the reptiles and that of the eutherian mammals.

Unfortunately the animal from which the specimens were taken had apparently been killed by drowning or strangulation, and in the death struggle blood-vessels in the labyrinth had ruptured; the resulting hæmorrhages are visible in the photograph and detract much from its value. The general outline of the organ is quite well preserved, but the finer details of the membranous structure are not shown. Owing to the difficulty of obtaining specimens of the monotremata, the writer has had to content himself with this one example.

In many respects the labyrinth of the platypus is more like that of some reptiles than of any of the other mammals which have been investigated. This statement refers only, of course, to the outward appearance; microscopically the structure, according to Pritchard and Alexander, resembles more closely that of the mammals than the general appearance would suggest. The superior canal does not present the rounded appearance so characteristic of the mammalia, but is distinctly angular. The cochlea has none of the whorls which are found in all the other mammals which have been examined, the most that can be said is that the first whorl is beginning to make its appearance. Too much stress, however, must not be laid upon this point, since it must be remembered that the number of mammals examined hitherto is limited, and it is quite possible that in some of the polyprotodont marsupials an intermediate stage of the cochlea may yet be found. At present, however, it may be stated that there is a large gap between the little hook-like process at the end of the cochlea of the monotremes and the one and a half or more whorls which characterise the hedgehog, the marsupial mole, the porpoise and sea-cow.

The length of the whole labyrinth is 10.25 mm. from the outermost point of the posterior canal to the tip of the cochlea. The diameter of the tube of the *cochlea* immediately in front of the round window is rather more than 1.25 mm., while the diameter of the *vestibule* in its longest axis is 2.75 mm.

The *superior canal* measures 3.0 mm. in its internal, and 4.5 mm. in its external diameter. The height of the vertex above the vestibule is 2.75 mm., and the diameter of the canal itself at the vertex is 0.5 mm. The *posterior canal* measures 2.75 mm. in its internal, and 3.5 mm. in its external diameter. The height of the vertex above the vestibule is 3.0 mm., and the diameter of the canal itself at the vertex is 0.75 mm. The *horizontal canal* is 2.5 mm. in its internal, and almost 4.0 mm. in its external diameter. The height of the vertex above the vestibule is 2.0 mm., and the diameter of the canal itself at the vertex is rather more than 0.75 mm. Thus the horizontal canal, though the shortest of the three, is also the thickest. The oval window measures 1.5 mm. in its longest axis. The length of the cochlea from the round window to the tip of the organ is 3.0 mm.

The aqueduct of the cochlea hardly deserves the name. It is represented by a narrow constriction between the cranial cavity and the perilymph space of the cochlea. The aqueduct of the vestibule must be a very fine tube ; the writer was not able to find it in the specimen examined by him, though it may probably have been present and been broken in the process of preparation.

The superior canal was referred to above as being angular. Leaving the ampulla it turns almost immediately at an obtuse angle and pursues a straight course upwards and backwards until it meets the upper limb of the posterior canal. At this junction there is no angular dip between the two canals. In other words, the common limb of the canals does not form a Y-shaped junction as in the great majority of mammals ; the only one of these in which the canals are arranged in at all a similar way is the sloth.

The posterior and horizontal canals are more regularly curved than the superior, indeed, the horizontal canal is very like that of other mammals. It lies, however, on a relatively lower plane, and its posterior limb opens into the ampulla of the posterior canal ; but it could not be definitely decided whether there was at this junction an actual communication between the endolymph spaces of the two canals.

The perilymph space is fairly well marked in the canals, though this is not so apparent in the superior as in the horizontal canal, owing to the shrivelling which has occurred in the former, the result of a partial drying of the specimen.

For the microscopic details of the monotreme labyrinth the reader is referred to the important papers by Pritchard and Alexander.

LITERATURE.—Hyrtl, *Op. cit.* S. 33, 58, 72. Ibsen, *Op. cit.* p. 46. Urban Pritchard, *Trans. Roy. Soc.* part ii. 1881. Alexander, *Zentralblatt f. Physiolog.* Heft 17, 1903. Denker, *Bericht. über d.* 10*te Versamml. d. deutsch. otolog. Gesellsch. zu Breslau*, 1901. Eschweiler. *Anat. Anzeiger*, Bd. xvi. S. 584.

THE VENOUS SYSTEM OF THE LABYRINTH OF MAMMALS

The writer's method of preparing the labyrinth is particularly suitable for the purpose of studying the distribution of the vessels in the organ ; and it may not be out of place therefore, to give a short description of the veins as seen in some of the specimens. The method of injection was not employed, since in some of the specimens the veins were already filled with blood. In some, the object was first stained with eosin, which brings into prominence small veins that might otherwise escape observation. The human labyrinth was examined in this way.

While the labyrinth is supplied with blood through a single artery, it is interesting to note that the organ is drained in several ways. It is as though the importance of adequate drainage is almost greater than that of a good supply of arterial blood. The necessity for securing efficient drainage in all tissues is obvious, but on consideration it will be seen that in the labyrinth it is even more imperative than in most other structures. In this organ the veins are not supported by the surrounding tissues as in other parts of the body, but are bathed by watery liquids, and for this reason there is more liability to rupture should any blockage occur. But this is not all. The vessels have to pass through narrow bony channels before they reach the sinuses within the cranium into which they empty themselves, and in this part of their course they cannot dilate in order to accommodate any increased amount of blood. The liability to distension and hæmorrhage, therefore, is very great, and it is necessary that ready and adequate drainage should be provided. The organ might be partially deprived of its blood supply for some time without serious harm, but a blockage in the drainage system, even for a few moments, might be followed by results which would permanently destroy the delicate structures of the organ of Corti and cristæ acusticæ for all functional purposes. In proof of this it may be mentioned that it is not at all uncommon to find hæmorrhages into the labyrinth of animals which have been strangled. Such an accident occurred in the case of the platypus, the labyrinth of which is shown on p. 80, vol. ii.

The blood is drained from the labyrinth by three different channels: (1) by a vessel which accompanies the aqueduct of the cochlea; (2) by a vessel which accompanies the auditory nerve; (3) by a vessel which accompanies the aqueduct of the vestibule.

Of these the first appears to be the most important and to drain the largest area. Although, as just stated, this vessel accompanies the aqueduct of the cochlea, it nevertheless has a bony channel of its own which runs parallel to that of the aqueduct. Unfortunately, its preparation for the purpose of demonstration is very difficult, and the only specimen in which it was completely seen has since been broken. Portions of both vein and aqueduct can be seen in Plate I., vol. i. They arise close together, the vein leaving the cochlea a fraction of a millimetre behind the aqueduct. In the plate referred to, the latter structure has been broken off short, and only the stump is visible ; but the vein, though bent out of its naturally straight course, remains intact. It is seen turning in under the cochlea instead of running parallel with the aqueduct, as it really does. This vein is formed by the junction of those which come in from the cochlea, from the ampullæ of the three canals, and from the vestibule. All the blood from the cochlea passes through this channel, into which it is discharged from a vein descending spirally round the modiolus. This spiral vein is formed by the union of three different sets of venules. These converge like the spokes of a wheel, the first set coming inwards from the outer surface of the whorls and passing along the under surface ; the second set coming inwards with the nerves through the lamina spiralis, while the third set passes inwards along the upper surface of the whorls. Of these sets the first and third are best seen in the labyrinths of man (Plate II., vol. i.), and of the porpoise (Plate V., vol. ii.). The second set consists of much shorter vessels, and is best seen in the lowest whorl of the cochlea of the seal (Plate XIX., vol. i.). The spiral vein, which is formed by the junction of these, descends the cochlea just outside the modiolus and joins the vessel which accompanies the aqueduct of the cochlea, as described above. (Plate XV., vol. i.).

But, in addition to the veins from the cochlea, there are others derived from the vestibule and the canals which also empty their blood into the vein which passes out, as described, parallel to the aqueduct of the cochlea. In Plate II., vol. i., it will be seen that a vein comes from the ampulla of the posterior canal and another from the vestibule; these join the vein from the cochlea just before it leaves the floor of the scala tympani. Further, in Plate XIX., vol. i., it will be seen that veins leave the ampullæ of the superior and horizontal canals, and that they unite to form one vein which passes backwards over the outer surface of the vestibule to leave the labyrinth along with those already described.

Thus it is shown that the blood is drained from all portions of the labyrinth by way of the vein which leaves the organ at the floor of the scala tympani near the opening of the aqueduct of the cochlea.[1]

The second channel of drainage is by way of the internal auditory meatus. This is best illustrated in Plate XIX., vol. i. If the ampullæ of the superior and horizontal canals be examined, it will be seen that from each of them there arise two tortuous veins, and that their method of distribution is peculiar and interesting. One of the veins from the superior ampulla joins one of those from the horizontal ampulla, and the resulting vein passes over the outside of the vestibule to join the veins from the cochlea, as described above. The remaining veins from the two ampullæ unite to form one, which leaves the organ in company with the auditory nerve. In the photograph this vein is seen cut off in the internal auditory meatus, or, to speak more correctly, on the posterior surface of the temporal bone, since there is, properly speaking, no internal auditory meatus in the seal. In this way each ampulla is drained by two quite different sets of vessels—one passing out through the bone along with the auditory nerve, and the other through the bone which forms the floor of the scala tympani. The vein which leaves the organ by way of the auditory nerve is very tortuous, while that which carries the blood to the floor of the scala tympani is comparatively straight.

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[1] For the phylogenetic significance of this vein, see p. 108.

The third channel by which the blood leaves the labyrinth is by a vessel which accompanies the aqueduct of the vestibule. This vein is seen in Plate I., vol. i. In the particular specimen from which this photograph is taken the vein passes through a bony canal of its own, but in many examples it is accommodated in the same channel as the aqueduct itself. The vein runs parallel to the aqueduct, and opens into the inferior petrosal sinus. This vessel drains the blood from a large part of the semicircular canals, though no doubt some finds its way out through the other veins described previously. (The distribution of the venules in the canals themselves may be studied in Plates II., XIX., and XXII., vol. i.). A network of minute veins is seen on the convex aspect of each canal, and these unite to form two vessels which run parallel to one another along the concave surface. These veins empty most of the blood from the canals into that vessel which has just been described as leaving the organ along with the aqueduct of the vestibule.

The general opinion is that there is no communication between the vessels of the labyrinth and those of the middle ear, and the result of these investigations, in agreement with those of Hyrtl, Eichler and Siebenmann, confirms this view. It should be noted, however, that Alexander and Politzer claim to have found such communication.

LITERATURE.—Hasse, *Anatom. Anzeiger*, 1886. Schwalbe, Ludwig, Festschr. 1886. Rauber, *Sitzungsber. d. Naturförsch. Gesellsch. zu Leipzig*, 1886. Politzer, *Arch. f. Ohrenheilk.* Bd. xi. Politzer, *Die anatom. und histolog. Zergliederung d. menschl. Gehör.*, 1889. Eichler, *Abhandlung. d. math.-phys. Kl. d. königl. sächs. Gesellsch. d. Wissensch* No. 5, 1892. Braunstein and Buhe, *Arch. f. Ohrenh.* Bd. lvi. Hft. 3 & 4, S. 261. Katz, *Arch. f. Ohrenh.* Bd. lvii. Hft. 1 & 2, S. 127. Habermann, *Arch. f. Ohrenh.* Bd. lvii. Hft. 1 & 2, S. 127. Alexander, *Arch. f. Ohrenh.* Bd. lvii. Hft. 1 & 2, S. 127. Siebenmann, *Die Blutgefässe im Labyrinth d. menschl. Ohr*, 1904. Shambaugh, *Arch. of Otology*, vol. xxxiv. No. 6.

BIRDS

GENERAL REMARKS ON THE LABYRINTH OF BIRDS

The comparative anatomy of the labyrinth of the birds has been studied less than that of any other of the divisions of the vertebrata. There are several reasons for this neglect, the most important being, perhaps, the fact that the whole division is outside the main stem of vertebrate descent. A second reason for the neglect of the study of the anatomy of the labyrinth of birds is the fact that, being so definitely specialised for flight there is less opportunity for development of the animal in so many different directions, and organs such as the labyrinth are apt to present more uniformity of type than in other divisions of the animal kingdom. In spite of this it is necessary that it should be done, were it only that in all scientific work gaps in our knowledge should be filled up where possible. It is curious to note that, from among the examples which have been studied by various anatomists many of the most interesting orders are absent. Such, for example, are the ratitæ and tinamiformes which, as will be seen later, present peculiar characters.

Further, it is to be added, that errors have crept into the description of the anatomy of the avian labyrinth owing to the fact that these descriptions have been arrived at by piecing together observations made from microscopic sections.

The most striking difference between the labyrinth of the bird and that of the mammal is, of course, the absence of any complete spiral appearance in the cochlea of the former. In this respect, however, it must be remembered that among the mammalia the monotremes show but little evidence of a spiral shape in the organ, and, so far as this is concerned, there is a slight curvature of the organ in the bird corresponding to that of the monotremes. With the exception of the monotremes, however, the labyrinth of the bird resembles that of the reptiles more than that of the mammalia, if the proper reptiles are selected for comparison. To say, however, that the labyrinth of the bird resembles that of the reptile, without any qualification, as is so frequently done, is to make a very obvious error. As a matter of fact, the typical labyrinths of these two divisions of the vertebrates are as unlike one another as it is possible for two labyrinths to be. Of all the reptiles which have been examined, only in the alligator does the labyrinth show any real similarity to that of the bird. There is also a slight resemblance between the labyrinths of the iguana and hatteria and that of the bird, but in these cases the similarity is not great.

One of the most striking differences between the labyrinth of the bird and those of the great majority of reptiles is in the appearance of the vestibule. In all the birds this cavity is very small, and to this rule there is no exception; in the great majority of reptiles, on the other hand, the vestibule is by far the largest part of the labyrinth. Further, in the reptiles the canals surround the vestibule, as it were, while in the birds and the mammals they lie entirely away from it. Again, in the reptile the otolith structures are large, and fill the vestibule in very great part, a condition which is not found in the bird or the mammal. With regard to the canals themselves, these structures are angular in the great majority of reptiles, while in the bird they are always rounded, as is also the case in the mammalia. In addition to these distinctions there are other differences between the two divisions, but these will be discussed separately. At present it is only of importance to point out that the resemblance between the labyrinth of the birds and the reptiles, which is so frequently referred to, only applies to one order of the latter division, the crocodiles, at least so far as investigations have hitherto shown.

Pigment is rarely found in the labyrinth of the bird in sufficient quantities to be seen by the naked eye; it has been found only in the labyrinths of the ostrich, the tinamou, and the rhea. When present the pigment is distributed most abundantly over the perilymph recess and adjacent parts of the cochlea and on the upper surface of the vestibule. It is, however, a curious fact that in the birds mentioned pigment is also found in the nerves when passing through the bone, and there appears to be little doubt that the pigment is continuous with that found in the dura mater of the cranial cavity of these birds.

The arrangement of the canals in the bird is much the same as that found in the mammalia: that is to say, the three canals are set approximately at right angles to one another, and the ampullæ of the horizontal and superior canals are at the anterior terminations. There is, however, one feature about the arrangement of the canals in the birds which is quite different from that in the mammalia. In the bird there is a communication between the horizontal and posterior canals at the point at which the former passes under the latter. The communication occurs between the perilymph spaces only of the canals, the endolymph spaces remaining entirely apart. This fact may have some physiological significance at present unknown. In the mammalia this communication was not supposed to exist, but, as will be remembered, it was found by the writer in the case of the common mole, the marsupial mole, the phascologale, and, more doubtfully, in the dromedary (vol. i., p. 145). In spite of these exceptions, however, it is undoubtedly the case that this communication between the two canals is an important one. It is one of the features in which the labyrinth of the bird resembles that of the reptiles more closely than does that of the mammalia, for the channel is, as a rule, found in the reptiles. Before concluding the reference to this characteristic feature of the labyrinth of the bird, it must be noted that it is not uniform throughout the division, as has been supposed, the writer having discovered two exceptions to the rule, these being the ostrich and the apteryx. These exceptions are particularly interesting when we remember that they both are regarded as being rather less distantly removed from the reptilian stock than almost any other. The only other birds of those examined that can claim anything like the ancient lineage of the ostrich and apteryx are the rhea and the tinamou. In both of these the communication between the canals is present in quite the usual manner; but it is to be observed that both are New World species. We are thus faced by apparently contradictory facts. This communication, which is a usual, though not invariable, feature of the reptilian labyrinth, is absent from two of the very orders which are most closely allied to the reptiles, while those birds which are supposed to be more distant from the reptilian stock invariably possess it. Either the ancestors of the ostrich and apteryx possessed this channel of communication and gradually lost it while the other orders of birds retained it; or, the particular species of reptiles from which birds are descended did not possess it, and the majority of birds have acquired it. It is unfortunate that up to the present time the writer has not had an opportunity of examining the labyrinth of the emu or cassowary, an examination which might throw some light upon the relationship of these ancient and very interesting birds.

While referring to this communication between the posterior and horizontal canals, it may be mentioned that there is also a communicating channel between the superior and horizontal canal in some orders of birds. The labyrinth of the buzzard shows this arrangement very clearly, but the condition is rather the exception than the rule, being in this respect very different from that just described. When present the communication occurs in the posterior portions of the two canals, and not near their vertices, as is the case in respect to the communication previously described. In both cases the perilymph spaces only communicate, the endolymph spaces always remaining quite separate.

The dimensions of the canals in birds never vary to the same extent as in mammals, taking the cetacea and the lemurs as the two extremes of the latter division. In the writer's opinion this is explained by the fact that in birds the movements of the head are never so limited by ankylosis of the vertebræ as in the cetacea.

Speaking in general terms, it may be said that the canals vary more in their disposition than does the cochlea. There are, however, several characteristics about the canals which never vary, such as the constant number of three, as is the case in the mammalia. Again, the superior canal is almost invariably the largest of the three in the bird, and in this feature the division is quite unlike the mammalia, in which the posterior frequently and, even in one case, the cetacea, the horizontal is the longest. With regard to the perilymph space, it is never quite obliterated at any part in the course of the canals in the bird, this being the reverse of the condition found in the majority of the mammals. In this respect the labyrinth of the bird is similar to that of the reptile and amphibian. Referring to this matter it must also be pointed out that the endolymph space always occupies the outer portion of the bony canal, as in other divisions. The ampullæ of the canals vary considerably, both in regard to their relative size and to the complexity of the crista acustica. It may be said that in some examples, such as the buzzard, the ampulla is larger and more complex in structure than in any of the mammalia, reptiles, or amphibia which the writer has had the opportunity of examining. Along each lateral wall of the ampulla is a fan-shaped structure, and between these two, and therefore occupying the floor of the ampulla, is another portion of the neuro-epithelium. This latter portion varies in different orders. In some it consists of a single conical crest, while in other orders three crests are present. The writer has termed these the ‘simple’ and ‘complex’ types of cristæ respectively, and they are referred to in the text by these names. The planes in which the canals lie are approximately at right angles to one another, as in the mammalia—a rule which is certainly not invariable in the case of the reptiles.

Perhaps the most variable feature in the appearance of the canals of the bird is the shape of the superior canal. Further, it is interesting to note that this feature varies with the different orders, so that it may be of help in classification, which, in the birds, is a difficult subject, and has given rise to much discussion. The two types of the superior canal which the writer has found may be termed the ‘upright’ and the ‘drooping’ types. In the former the anterior limb of the canal rises almost vertically from the ampulla, and, having reached a certain height, turns comparatively sharply backwards in a horizontal direction, and finally curves downwards and forwards to enter the vestibule again. As a result of this disposition the long axis of the canal is frequently almost vertical, as may be seen, for example, in the labyrinth of the pigeon. In the second type the anterior limb of the canal does not rise vertically from the ampulla, but passes upwards and backwards before curving downwards and forwards to enter the vestibule. Hence the long axis of the canal in this case is not vertical, but lies in a direction obliquely upwards and backwards, as may be seen in the labyrinth of the domestic fowl and the duck. In the description of the labyrinth of the individual birds the type of superior canal which it possesses will be mentioned, so that it is important for the reader to remember these names.

The vestibule of birds is a very small space; smaller, indeed, relatively to the rest of the labyrinth, even than in the mammalia. The saccule is much smaller than the utricle, and it is the latter cavity which contains the otoliths, which are usually of a size sufficiently large to be seen by the naked eye. Frequently there is one otolith present in the utricle, but occasionally two are found. They are flat, and lie in the horizontal plane, and are often triangular in shape, being similar to those found in rare cases in the mammalia such as the sea-lion and sea-cow. The apex of the triangle is directed forwards and the position which they occupy is the same as in the mammalia, that is, immediately internal to and behind the openings of the ampullæ of the superior and horizontal canals.

The aqueduct of the vestibule in the bird is not so long as in the mammalia, and indeed it appears rather as a perforation of the thin layer of bone which separates the vestibule from the cranial cavity, than as an actual tube. It is, however, very fine, and only in a few cases did the writer find it possible to preserve it in the course of preparation. The oval window forms an ellipse, which is broader than that of the mammalia. The round window is absent in some birds —*e.g.* the ostrich.

In its macroscopic features the cochlea of the bird is much simpler than in the mammalia, and it does not undergo so much variation as in the latter. It consists of a tube more or less curved, but never approaching the spiral type. It varies, however, considerably in length, being proportionately shortest in the ostrich and longest in the owl and thrush. The curvature is such that the convex surface faces downwards and forwards, and to a slight extent outwards. The cochlear branch of the auditory nerve runs from without inwards and forwards along the concave upper surface of the organ, and sends filaments in its course downwards through a small piece of cartilage to terminate in the basilar membrane. At the internal extremity a bundle is sent directly inwards, which, radiating in a fan-like manner, terminates in the lagena ; in some of the photographs these fibres may be seen. In order to understand the relationship of the structures contained within the tube of the cochlea, it is necessary to make transverse sections of the organ and examine them by means of the microscope. As the writer has no intention of considering this aspect of the subject, but only wishes to deal with the macroscopic appearances, the finer details will be mentioned as briefly as possible.

Immediately below the nerve of the cochlea is the cartilage just referred to, through which fibres pass to enter the basilar membrane. The latter membrane is attached along its upper margin to this cartilage, while below it is attached to a second plate of cartilage. These two plates of cartilage run along the cochlea from the vestibule, but at their inner extremity they meet at the lagena. The endolymph space of the cochlea is bounded on one side by the basilar membrane, as in the mammalia, while on the other sides it is bounded by another fine membrane which curves downwards and forwards from the upper cartilage to the lower. In the anterior and inferior portions of this membrane is a curious structure, the tegmentum vasculosum. This structure consists of a series of comparatively large venous spaces running out parallel to one another from a central vein. The appearance is not unlike that of a rake, the teeth of the rake lying in a direction transverse to the long axis of the organ. The tegmentum vasculosum runs the whole length of the cochlea, and does not, in all birds, stop at the termination of the basilar portion, as stated by Retzius, but occasionally passes inwards to the lagena, as may be seen in the labyrinth of the duck (Plate XXV.). In the thrush, on the other hand, it does stop at the end of the basilar portion, the veins of the lagena being in the form of a clump of intertwining vessels (Plate XXXVII.).

The membrane containing the tegmentum vasculosum of birds corresponds in part to the stria vascularis, and in part to the membrane of Reissner in mammals. The number of venous spaces in the tegmentum vasculosum varies in different birds, and the degree of its development indicates the richness of the blood-supply to the cochlea, and therefore the functional activity of the organ. Hence it is not surprising to find that of all the birds examined the thrush has this structure developed to the highest degree, there being fifty-eight venous spaces. In the duck there are forty-two, in the heron twenty-seven, and in the buzzard twenty-three. In the photograph of the labyrinth of the owl the tegmentum vasculosum hardly shows at all, the blood being distributed more in the canals and vestibule than in the cochlea at the time of death.

The other structures in the cochlea, such as the basilar membrane and the two cartilages, are so transparent that they are hardly seen in the photograph. The nerve itself, however, is opaque, and is seen at the upper margin of the organ. By means of the two cartilages and basilar membrane the cochlea is divided in its outer portion into two cavities, the scala tympani and the scala vestibuli. These two cavities communicate with each other through the helicotrema exactly as in the mammalia, and this may be seen in some of the photographs immediately internal to the point at which the nerve terminates before sending fibres inwards to the lagena. A large vein is frequently seen passing through the helicotrema. The scala tympani itself is also divided into two channels by means of the tegmentum vasculosum, and there are thus three channels corresponding to the scala tympani, the ductus cochlearis and the scala vestibuli of the mammalia. On passing inwards, however, towards the lagena the three channels become replaced by two, the scala tympani being obliterated by the union of its walls. The scala vestibuli also is much reduced in size, and the lagenar portion consists for the most part of the expanded termination of the ductus cochlearis. At the same time, the two slips of cartilages to which the basilar membrane is attached in the basilar portion become united and support the neuro-epithelium of the lagena.

The lagena is a saddle-shaped structure at the tip of the cochlea, with the concavity of the saddle facing downwards, and the cochlear nerve terminates, as described, by spreading out fan-like towards it, the fibres passing into the specialised neuro-epithelium which is found there. In the lagena there is found in most birds a collection of otoliths, which also are sometimes arranged in a saddle-shaped manner over the neuro-epithelium.

There remains to be described a structure which bulks largely in the labyrinth of the bird. This is a cavity known as the perilymph recess—recessus perilymphaticus or recessus scalæ tympani. It consists of a hollow sac which opens out of the scala tympani through a wide elliptical opening at the outer, inferior and posterior portion of the cochlea near the junction of the latter with the vestibule. The shape of the perilymph recess varies considerably in different orders, and the various shapes will be noted in the descriptions given to the individual birds; the commonest shape is roughly oval.

So far as the present writer's investigations go, the perilymph recess is present in all birds, though, in very rare cases, it is much reduced in size. It is, therefore, surprising that such careful anatomists as Retzius and Hasse, although aware of its existence in some birds, have not depicted it in others, such as the goose, the pigeon and the thrush, in which it is undoubtedly present. This is doubly unfortunate, since the omission has led to further errors, such as incorrect descriptions of the aquæductus cochleæ, and the failure to recognise the presence, or at least the correct course, of a small nerve which passes to the perilymph recess. Further, the perilymph recess has interesting phylogenetic relationships. No apology therefore is needed for giving a rather fuller and more correct description of the cavity than has been done before.

Seen from above, the usual shape of the cavity is oval (Plate XXV.); but when viewed from the outer aspect it will be noted that the nearest, that is, the outer anterior surface, is flat. Thus it is like an egg cut obliquely in half, the flat anterior and outer surface being occupied in its lower half by the round window (in those birds which have a round window) (Plate XXXIV.), and bordered above by the oval window.

The other surfaces of the perilymph recess are rounded in most birds. The outer extremity of the cavity reaches almost to the ampulla of the posterior canal, while the inner extremity is found behind the middle of the cochlea. At the outermost extremity the wall of the perilymph recess receives a small nerve twig which leaves the nerve to the posterior ampulla just before it enters the ampulla (Plates XVIII., XXVII., XXX.). The twig has pigment deposited in it, in those birds in which pigment is found in the other nerves of the labyrinth, *e.g.* the ostrich and tinamou. The writer cannot say at present what is the ultimate destination of this little nerve-twig, and it has not been described before. Retzius, however, describes a twig which also leaves the nerve to the posterior ampulla and goes to the macula neglecta in a direction almost the opposite to that found by the present writer. It may be found that the two nerves are really the same, but that Retzius has described its course incorrectly. The nerve described by the writer is present in most birds, and possibly in all, but may have been broken in those in which it is not seen.

The aqueduct of the cochlea—or ductus perilymphaticus, as it is sometimes called—is another structure which has been described incorrectly in the bird, owing in part to the failure to recognise the significance of the perilymph recess, and in part to the attempt to ascertain its relationships by the examination of a series of microscopic sections. Retzius, with his deep anatomical insight, realised this last difficulty, and does not pretend to have found it. He injected coloured fluid into the tip of the cochlea and found that it penetrated into the cranial cavity behind the middle of the organ, presumably by way of the aqueduct of the cochlea; but he admits his inability to find the tube in microscopic sections. Hasse and Breschet, on the other hand, thought that they discovered it as a very fine tube leaving the scala tympani close to the round window and, passing upwards through the wall of the cochlea, opening into the cranial cavity behind the middle of the cochlea. The only correct portion of this description is the statement that the duct opens behind the middle of the cochlea.

The real relationships and course of the aqueduct of the cochlea may be seen in several of the photographs, and it will be observed that it varies both in calibre and position in different birds. In perhaps the majority of birds it opens obliquely out of the posterior and inner wall of the perilymph recess, and, as a comparatively wide tube, curves upwards in close contact with that cavity and opens behind the middle or outer third of the cochlea. Examples of this type are the heron (Plate XXIV.), the buzzard (Plate XXVI.), and the carrion crow (Plate XXXIV.). In some birds, however, the aqueduct of the cochlea rises from the inner and upper extremity of the perilymph recess, and after running a very short course through the bone, opens into the cranial cavity behind the middle of the cochlea. In these birds the aqueduct is finer than in the type previously described; such, for example, are the ostrich (Plate XVII.), the tinamou (Plate XXVII.), and the thrush (Plate XXXVII.). In a number of the photographs the aqueduct is not seen, owing either to the fact that it has been broken off in preparation, or to the position from which the photograph was taken.

It is interesting to note that in birds, as in mammals, the blood is drained from the cochlea by a vein which accompanies the aqueduct of the cochlea. In several of the photographs it will be seen that a comparatively large vessel comes through the helicotrema, passes outwards along the cochlea, turns over on to the perilymph recess, and after uniting with vessels from other parts of the labyrinth, passes out in company with the aqueduct (Plates XXV., XXVI., XXXVII.).

But the interesting features of the perilymph recess do not end here, for it has phylogenetic relationships which have only in part been demonstrated hitherto. Retzius and other anatomists have found the perilymph recess in the reptiles, and the present writer has found it in the teguixin and in the stump-tailed lizard, in that irregular collar which partially surrounds the base of the cochlea, and which contains the aqueduct of the cochlea.

In the mammals, on the other hand, the vestige of the perilymph space has not yet been described owing to the fact that differences in shape of the cochlea have not received sufficient attention. Nevertheless, it is true that in many mammals there is a very definite vestige of the perilymph recess in that bulging of the floor of the scala tympani described by the writer (vol. i., Plates XIII., XIV., XXII., and vol. ii., Plate X.). In the kangaroo the bulging is so marked that it might be allowed to retain the name perilymph recess, as in birds and reptiles. Thus it comes about that, in all mammals in which the bulging of the floor of the scala tympani is present, the aqueduct of the cochlea leaves the labyrinth at the most prominent part of the bulging, the remaining portions of the perilymph recess having been gathered in, as it were, to form the floor of the scala tympani in this region. In some mammals, such as man and the primates in general, the bulging has completely disappeared and the aqueduct opens abruptly from the floor of the scala tympani.

Further, we can now understand why the main channel for the drainage of blood from the labyrinth should be by the vein accompanying the aqueduct of the cochlea (see p. 86. vol. ii.). In the reptile this is by far the widest communication through the bone between the cranial cavity and the labyrinth, and the same is generally, though not always, true of birds and mammals. In man, however, the bony channels containing the aqueduct of the cochlea and the accompanying vein have become long and extremely fine. This is a point to which pathologists and aurists might pay particular attention, since obstruction, both to the drainage of blood and to the flow of the perilymph, might occur very easily and lead to difficulties in the blood-supply of the organ and to interference with the tension of the intra-labyrinthine fluids respectively.

Before proceeding to describe the individual labyrinths of the birds, it should be noted that the classification adopted is that of Gadow, as drawn up in his work, 'A Classification of Vertebrata, Recent and Extinct.' Examples have been obtained of all the orders except Sphenisciformes (Penguins) and Procellariiformes (Puffins, &c.). In a few orders two examples are given.

The anatomy of the labyrinth of birds is not so well known to the great majority of anatomists as is the mammalian labyrinth. In order, therefore, to help the reader, lettering has been applied to two of the plates, and it will very materially assist him if he studies these plates carefully before beginning to read the text and examine the remaining plates. The lettering naturally diminishes the beauty of the photographs, and for that reason has been restricted to Plates XXX. and XXXIV.

ERRATUM

Page 108, line 2, *for* space *read* recess

RATITÆ

PLATE XVII

THE RIGHT MEMBRANOUS LABYRINTH OF THE MASAI OSTRICH

Struthio masai

× 3

The organ is viewed from the outer aspect and is rotated counterclockwise to the extent of about 30°. The superior canal is of the drooping type and the cristæ in the ampullæ are simple. In the middle of the vestibule is seen the oval opening of the aqueduct of the vestibule. The flat triangular otolith is seen edgewise immediately behind the ampullæ of the superior and horizontal canals. The nerves are deeply pigmented, including the twig passing from the nerve of the posterior ampulla to the perilymph recess (see text). The cochlea is small, particularly in the basilar portion, and there is a sharp beak at the tip of the lagena. The perilymph recess has two nipple-like projections, that nearest the tip of the cochlea being the aqueduct of the cochlea. The lower portion of the perilymph recess has been broken off. It may be seen undamaged in Plate XVIII.

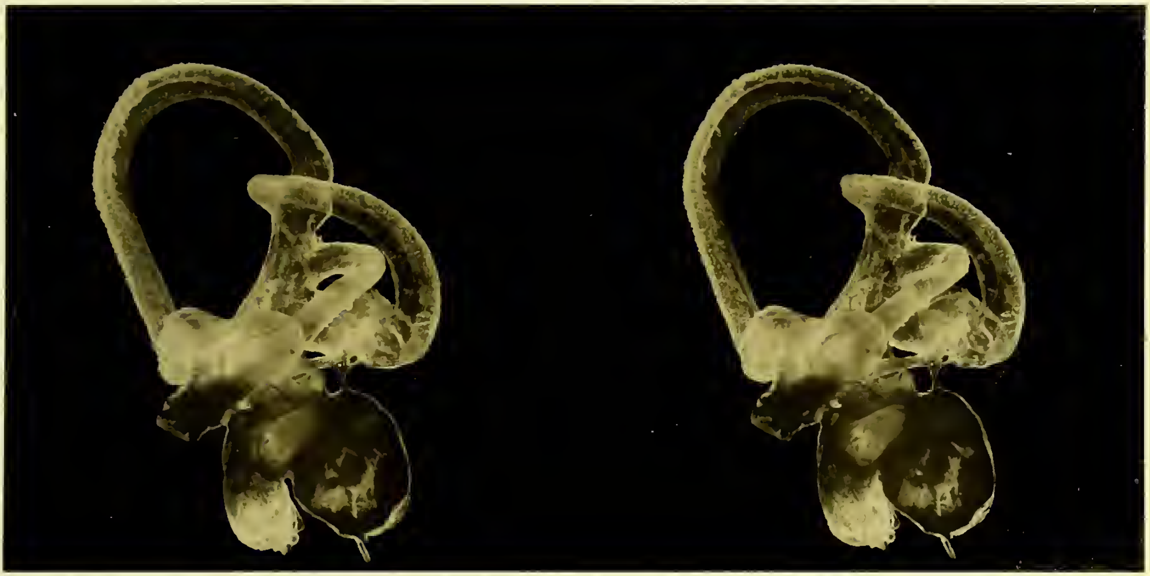
PLATE XVIII

THE LEFT MEMBRANOUS LABYRINTH OF THE MASAI OSTRICH

Struthio masai

× 3½

The organ is rotated counter-clockwise to the extent of about 45°. The photograph shows that the usual communication between the posterior and horizontal canals is absent. The nerve twig from the posterior ampullary nerve to the perilymph recess is very clearly seen, and is deeply pigmented, as is also the large perilymph recess. The oval window is seen a little obliquely, but the round window is absent in the ostrich, and in this respect the photograph should be compared with that of the labyrinth of the carrion crow (Plate XXXIV.) in which the round window is seen.



STRUTHIONES

THE MEMBRANOUS LABYRINTH OF THE MASAI OSTRICH

Struthio masai

The author has already published, in the 'Proceedings of the Royal Society of London' (B. vol. lxxviii, p. 284), a description of the labyrinth of the Masai ostrich. Since, however, the specimen from which that description was taken was broken, it will not be out of place to give a more complete and correct account of this which is in many respects the most interesting labyrinth of the birds.

The labyrinth is the largest found in any bird, but since the cochlea is small, the actual length is little more than that of the gannet. Indeed, the whole organ is not so much larger than that of the latter as one would expect, considering the differences in the size of the two birds; but it must be remembered that the head of the ostrich is small in proportion to the body, and the labyrinth bears a closer relationship to the size of the head than to the size of the body.

The whole organ measures 18.0 mm. from the vertex of the superior canal to the tip of the cochlea. The *cochlea* has a length of 6.0 mm. from the tip to the anterior margin of the oval window. The diameter of the tube of the cochlea opposite the oval window is 2.5 mm.

The *vestibule,* which is rather small, measures 3.5 mm. in its longest diameter, and the major axis of the oval window has a length of 2.5 mm.

The *superior canal* measures 7.5 mm. in internal, and 11.0 mm. in external diameter. The height of the vertex of the canal above the vestibule is 9.5 mm., and the diameter of the canal itself at the vertex is rather more than 1.5 mm. The *posterior canal* has internal and external diameters of 5.5 mm. and 8.5 mm. respectively. The height of the vertex of the canal above the vestibule is 3.5 mm., and the diameter of the canal itself at the vertex is 1.5 mm. The *horizontal canal* measures rather more than 4.0 mm. in internal, and 8.5 mm. in external diameter. The height of the vertex of the canal above the vestibule is 4.0 mm., and the diameter of the canal itself at the vertex is 1.5 mm.

The perilymph space is well marked in all the canals, and the ampullæ are relatively rather small. The cristæ acusticæ of the ampullæ are simple, there being only one crest in that portion which lies on the floor of the ampulla. In the labyrinth of the ostrich there is no communication between the posterior and horizontal canals at the point at which they cross; the only other bird of those which have been examined that is possessed of this peculiarity is the apteryx. The significance of this condition has already been discussed on page 92, and there is, therefore, no need to refer further to the subject at present. Otoliths of a size sufficient to be recognised by the naked eye are found in the vestibule. In some examples only one otolith was found, while in others two were present. The otoliths are flat, and are found in the usual place immediately behind and internal to the ampullæ of the superior and horizontal canals. The aqueduct of the vestibule is represented by an oval opening on the upper surface of the vestibule very similar to that found in the apteryx.

The cochlear portion of the labyrinth is almost as peculiar as the canals and vestibular portions. In its general appearance the cochlea is short and thick, and at the tip there is a peculiar beak-like projection inwards. This projection is very characteristic, and, since it was found in all the four specimens examined, is not a mere individual abnormality. It is present to a slight extent in the rhea, and in both birds the tip of the organ is unlike that of any other, whether of the rounded or bulbous shape. In none of the specimens examined could any trace of the tegmentum vasculosum be seen, and if further examination corroborates this finding, then the ostrich is unique among birds in this respect. The basilar portion of the cochlea is extremely short, as may be seen in Plate XVII., in which the vein passing through the helicotrema indicates its termination. The insignificant size of this portion of the cochlea and the apparent absence of the tegmentum vasculosum may possibly be associated with the fact that the ostrich is a 'decidedly silent bird' ('Cambridge Nat. Hist.,' vol. ix. p. 29), though it occasionally utters a hoarse, mournful note. The writer has not been able, however, to learn, on reliable authority, whether the bird's sense of hearing is acute or not.

The perilymph recess is large and roughly oval. On its upper wall there are two projections, one at the inner and the other at the outer extremity. The inner one is the aqueduct of the cochlea, but the outer one appears only to give passage to a blood-vessel. The somewhat unusual position of the aqueduct of the cochlea has already been referred to on p. 107. The surface of the perilymph recess and cochlea, except the tip, is covered with pigment. The actual deposit is not quite so regular as that found in the tinamou, but the surface covered is much more extensive. The nerves of the labyrinth are also covered with pigment, and even the twig which the perilymph recess receives from the nerve to the posterior ampulla is pigmented.

A collection of small otoliths is present in the lagena.

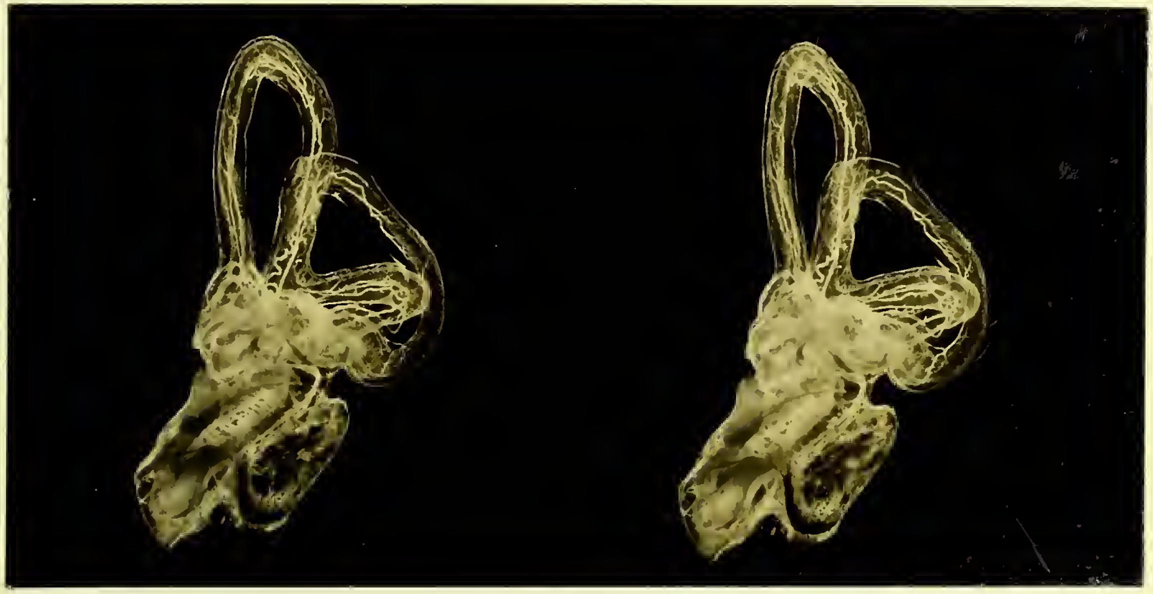
PLATE XIX

THE RIGHT MEMBRANOUS LABYRINTH OF THE AMERICAN RHEA

Rhea americana

The organ is suspended by the superior canal and is viewed from behind. The veins are dilated in all parts of the labyrinth, and in the perilymph recess there is a blotchy deposit of pigment. The superior canal is of the drooping type, and the perilymph space is well developed in all the canals. In transverse section the ampullæ are triangular in shape, as is seen in the ampulla of the superior canal. There is a communication between the posterior and horizontal canals, this labyrinth differing from those of the ostrich and apteryx in this respect. The cristæ acusticæ in the ampullæ are not complex. The cochlea is short relatively to its breadth, and the perilymph recess is large and oval in shape. A nerve is seen running from the branch which supplies the posterior ampulla across to the external wall of the perilymph recess.

The cartilaginous framework within the cochlea is seen to consist of one piece of cartilage bent sharply upon itself at its outer part, and not of two different cartilages, as is usually described. The tegmentum vasculosum is well shown on account of the venous congestion. The helicotrema is seen to the left, near the tip of the cochlea, with a vein passing through it. The cochlear nerve is short and thick, and is seen above the upper limb of the cartilaginous framework. The otoliths in this labyrinth are small, and are only seen in the lagena.



RHEÆ

THE MEMBRANOUS LABYRINTH OF THE AMERICAN RHEA

Rhea americana

It is unfortunate that the labyrinth of the rhea was not measured before it was finally put into xylol owing to a mistake on the part of the writer; and it is impossible to measure accurately the various parts after the paraffin has been removed. The measurements, therefore, cannot be given, but it may be said that, as regards size, the organ is a little smaller than that of the ostrich.

The superior canal is of the drooping type, but is not particularly like that of the ostrich, the latter forming a broader ellipse. There is a communication between the perilymph spaces of the horizontal and posterior canals, a feature in which this labyrinth is similar to those of the great majority of birds, and unlike those of the apteryx and ostrich. Further, pigment is present only in small quantities on the perilymph recess. The cochlea of the rhea, like that of the ostrich, is relatively short, and is also similar to the organ as found in the ostrich in that the tip of the organ is pointed, a condition the reverse of that found in almost all other birds. The perilymph recess is very large in both the rhea and the ostrich, in fact it may be said that in these animals this cavity reaches its greatest development.

In the rhea there is to be found, as in most birds, that nerve twig which passes from the branch to the posterior ampulla across to the perilymph recess. It is clearly shown in the photograph, but is not pigmented as in the ostrich and tinamou. The ampullæ of the canals are almost triangular in transverse section, but are not proportionately quite so large as in many birds, neither is the arrangement of the neuro-epithelium of the ampullæ complex in its disposition, though the fan-like distribution at the sides of the ampullæ may be seen in the photograph.

The otoliths of the rhea are not a marked feature of the labyrinth; indeed, in the vestibule none were to be found of a size sufficient to be recognised by the naked eye in either of the specimens examined. At the tip of the cochlea, however, a small otolith was found, but it was not so large as those usually seen in this situation.

In the labyrinths of the rhea examined by the writer the veins were dilated with blood, and consequently they may be seen very clearly in the photograph. One of the veins in particular may be seen running through the helicotrema on the upper surface of the cochlea near the tip of the organ. Further, in consequence of the filling of the veins with blood, the tegmentum vasculosum is seen very clearly. In this feature the rhea is very different from the ostrich, in which the tegmentum vasculosum was not found at all. The number of parallel venous spaces in this structure is small in the rhea, reaching only to about twenty, as compared with fifty-eight in the thrush.

Although the cochlea is relatively short in the rhea, it is distinctly longer than in the ostrich, and this applies in particular to the basilar portion. The perilymph recess is large, but the aqueduct of the cochlea is not seen in the photograph, so that no comparison can be made between the birds in this respect.

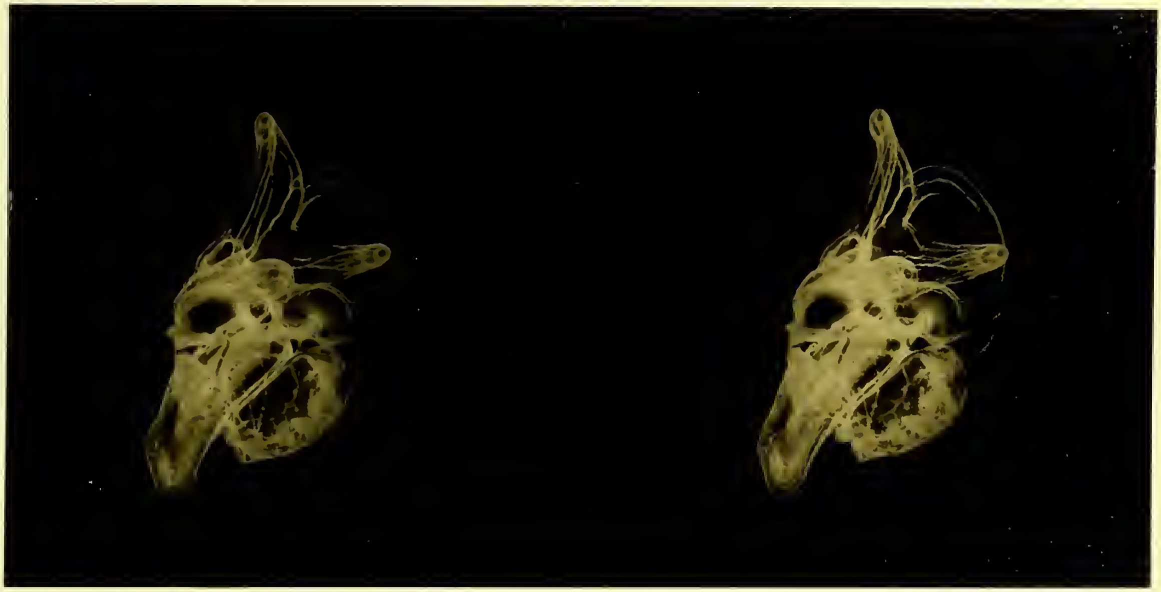
PLATE XX

THE RIGHT MEMBRANOUS LABYRINTH OF MANTELL'S APTERYX

Apteryx mantelli

× 5

The organ is suspended by the superior canal and is viewed from behind. The perilymph space is well marked in all the canals. There is no communication between the posterior and horizontal canals, the labyrinth in this respect being similar to that of the ostrich. The cristæ acusticæ in the ampullæ are not complex. A branch from the nerve to the posterior ampulla is seen running across to the perilymph recess. The aqueduct of the vestibule is seen as an oval opening on the same level as, and immediately internal to the ampulla of the posterior canal. The large black mass in the vestibule is the otolith, which is proportionately larger in the apteryx than in any other bird. The hazy outline of the otolith as seen in the photograph is due to diffraction. The cochlea is relatively thick in proportion to its length, and the perilymph recess is very large. The cochlear branch of the auditory nerve is short and thick. An otolith is present in the lagena.



APTERYGES

THE MEMBRANOUS LABYRINTH OF MANTELL'S APTERYX

Apteryx mantelli

As might well be understood, the labyrinth of the apteryx is one of the most interesting of those of the birds, hardly surpassed indeed by that of the ostrich, with which it has some features in common.

The whole organ measures 10.5 mm. in length from the outermost point on the vertex of the superior canal to the innermost point on the tip of the cochlea. The diameter of the *cochlea* just in front of the oval window is 2.0 mm., and the length of the organ from the front of the oval window to the tip is rather more than 2.5 mm. This proportion of length to breadth might not at first sight appear to be correct, judging from the photograph, but it must be pointed out that the anterior margin of the oval window is placed some distance from the beginning of the cochlea. The cochlear nerve is comparatively small, and appears as a stump on the upper surface of the organ. The tegmentum vasculosum contains a considerable number of parallel venous spaces, and the basilar portion of the cochlea appears to be altogether more highly developed than in the ostrich. The development of the cochlea, however, falls short of that of most birds, especially in regard to the size of the nerve. The lagena forms a very large part of the cochlea, and, as a result of this disposition, the helicotrema is found almost in the middle of the upper surface of the organ. An otolith of considerable size is found in the lagena along the anterior border. The tegmentum vasculosum is well marked, and the perilymph recess is oval and large, being, in fact, of greater cubic capacity than the cochlea itself.

The *vestibule* is a difficult cavity to measure in the bird on account of its irregular shape, but its greatest diameter in the apteryx is rather less than 3.0 mm. There are two features of particular interest in the vestibule of the apteryx, the otolith and the aqueduct of the vestibule. With regard to the first of these it may be said that the otolith of the vestibule is the largest found in any animal higher than the reptiles. It is oval in shape, and occupies a considerable portion of the vestibule, forming the most important feature of the cavity, not an insignificant crystal as in other birds and in mammals. It is seen in the photograph as a dark mass in the utricle, but is in reality white in colour. The blurred edges in the photograph are due to the diffraction of light caused by the edges of the structure. It is interesting to note, moreover, that the otolith does not consist of a single crystal, but of an accumulation of numerous small ones, as in the reptiles and amphibia. The other feature of interest in the vestibule is the aqueduct. To term it an aqueduct, however, is hardly correct, since it consists of a comparatively large elliptical opening on the posterior surface of the temporal bone. It is seen very clearly in the photograph situated between the otolith and the ampulla of the posterior canal. The writer has not found the aqueduct of the vestibule in any other bird similar to that of the apteryx; but, since it is usually a difficult structure to find, there may be other examples of this peculiar condition. The writer, however, is inclined to think that in this respect the bird under consideration is really unique, since the condition is not present in the rhea, the ostrich or the tinamou: that is to say, in the very species in which one might expect to find it. It would be interesting to look for this condition in the emu and the cassowary.

The oval window is large, measuring 1.0 mm. in its longest diameter.

The *superior canal* measures 4.0 mm. in internal, and rather less than 6.0 mm. in external diameter. The height of the vertex of the canal above the vestibule is 4.5 mm., and the diameter of the canal at the vertex is 1.0 mm. The superior canal in the apteryx is not so large relatively to the other two canals as is usual. Further, the posterior portion of the superior canal in the apteryx turns at an angle rather than as a gradual curve, such as is found in all other birds. This peculiarity may be a remnant from the reptilian type of cochlea, for as will be seen later, in the reptiles this canal is usually angular. The *posterior canal* measures 3.0 mm. in internal, and 4.0 mm. in external diameter. The height of the vertex of the canal from the vestibule is 2.0 mm., and the diameter of the canal itself at the vertex is 1.0 mm. The *horizontal canal* measures 2.5 mm. in internal, and 4.0 mm. in external diameter. The height of the vertex of the canal above the vestibule is 2.5 mm., and the diameter of the canal itself at the vertex is 1.0 mm. The perilymph space is well marked in all the canals.

In the labyrinth of the apteryx there is no channel of communication between the horizontal and posterior canals, this disposition being peculiar to it and the ostrich. The horizontal canal does not pass so far back as the plane of the posterior canal, the apteryx in this respect being unique among birds.

The cristæ acusticæ of the ampullæ are simple, there being only one crest in that portion of the neuro-epithelium which lies on the floor of the ampulla.

The aqueduct of the cochlea arises from the innermost portion of the perilymph recess, and a minute trace of pigment is present on the posterior wall of that cavity.

CARINATÆ

PLATE XXI

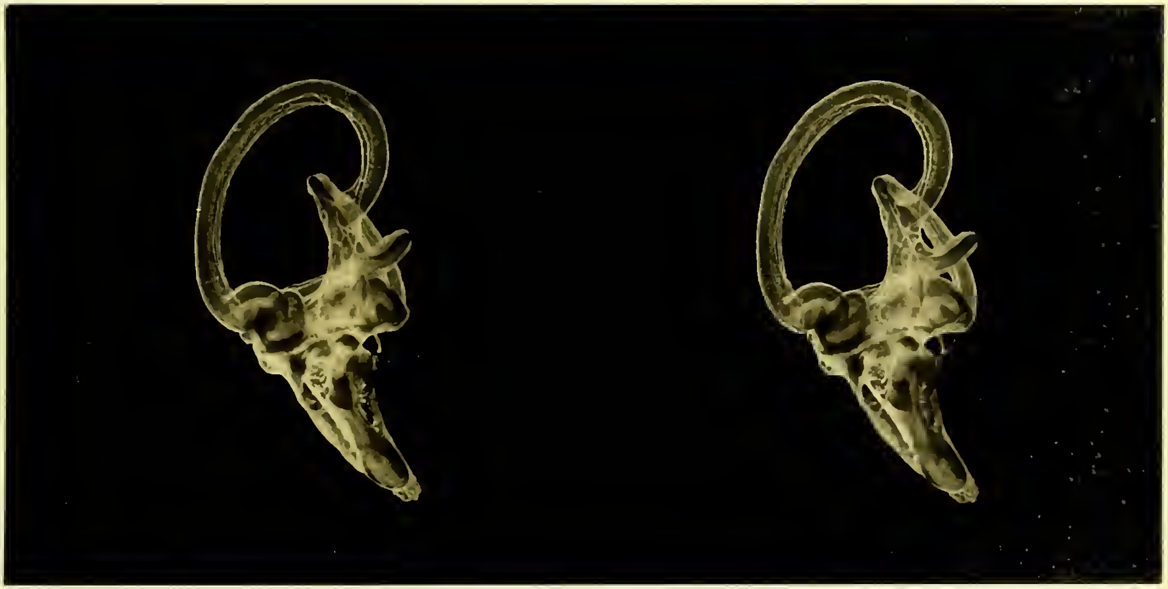
THE RIGHT MEMBRANOUS LABYRINTH OF THE RED-THROATED DIVER

Colymbus septentrionalis

× 4

The organ is suspended by the posterior and superior canals, and is rotated a little counter-clockwise: it is viewed from the inner aspect. The perilymph space is not particularly well marked. A small amount of pigment is seen scattered over the vestibule, and particularly about the aqueduct of the vestibule, which is seen in the form of an inverted V close to the posterior opening of the horizontal canal. A branch from the nerve to the posterior ampulla is seen crossing over to the remains of the perilymph recess, which has broken off. The superior canal is of the drooping type. The cochlea is occupied for the most part by the lagena, but in the specimen represented a portion of the anterior wall near the tip has been cut off.

The posterior limb of the superior canal is separated from that of the horizontal canal by a considerable space.



COLYMBIFORMES

THE MEMBRANOUS LABYRINTH OF THE RED-THROATED DIVER

Colymbus septentrionalis

The colymbiformes are admittedly an archaic type of bird, but judging from the labyrinth they mark a distinct advance on the ratitæ, at least, so far as can be gathered from those described in the preceding pages.

The labyrinth of the red-throated diver measures 13.0 mm. from the vertex of the superior canal to the tip of the cochlea. The diameter of the tube of the *cochlea* just in front of the oval window is 2.0 mm., and the length of the organ from the front of the oval window to the tip is 4.5 mm. The cochlea is a somewhat pointed structure, being in this respect unlike that of most birds. The lagena is long, and there is the usual collection of otoliths in this region. The helicotrema is not so near the tip of the organ as is usual in birds, but is placed about the middle, as in the apteryx. The perilymph recess has been broken, and its size and shape cannot be reported, but the twig which it usually receives from the nerve to the posterior ampulla is present.

The *vestibule* measures 4.5 mm. in its longest diameter, and the major axis of the oval window 1.75 mm. A comparatively large otolith is found in the usual place—that is, immediately behind and internal to the openings of the ampullæ of the horizontal and superior canals.

The *superior canal* measures 6.0 mm. in internal, and 7.75 mm. in external diameter. The height of the vertex of the canal above the vestibule is 5.75 mm., and the diameter of the canal itself at the vertex is 1.0 mm. The *posterior canal* measures 4.0 mm. in internal, and 6.0 mm. in external diameter. The height of the vertex of the canal above the vestibule is 3.0 mm., and the diameter of the canal itself at the vertex is 1.0 mm. The *horizontal canal* has internal and external diameters of 4.25 mm. and 6.25 mm. respectively. The height of the vertex of the canal above the vestibule is 3.5 mm., and the diameter of the canal itself at the vertex is 1.0 mm.

The perilymph space is not very well marked in the canals.

The superior canal is distinctly of the drooping type, and the ellipse which it forms is much narrower than that of the gannet. The posterior limb of the superior canal does not descend low, so that there is no communication between it and the posterior limb of the horizontal canal, though, of course, the usual communication between the horizontal and posterior canals is present. The non-ampullary ends of the superior and posterior canals unite and form a common crus some little distance from the vestibule, and in this respect the labyrinth is in contrast with that of the gannet, in which all three canals open into the vestibule together.

The cristæ acusticæ of the ampullæ are complex, there being three crests in that part of the neuro-epithelium which lies on the floor of the ampulla. The fan-like structures on the lateral walls of the ampullæ are present as usual.

A minute trace of pigment is present on the upper surface of the vestibule at the point at which the aqueduct leaves the cavity. It is in the shape of an inverted V, and may be seen in the photograph demonstrating the position of the aqueduct.

The cochlea is almost straight, and should be compared with those of the domestic hen, the crow and several others. The cochlear nerve is very short, and the portion which goes to supply the basilar portion of the organ is small. As stated above, the lagena is large, and altogether it would appear that the basilar portion is relatively poorly developed.

LITERATURE.—Huschke, *Arch. f. Anat. Physiolog. u. Wissensch. Med.* 1835.

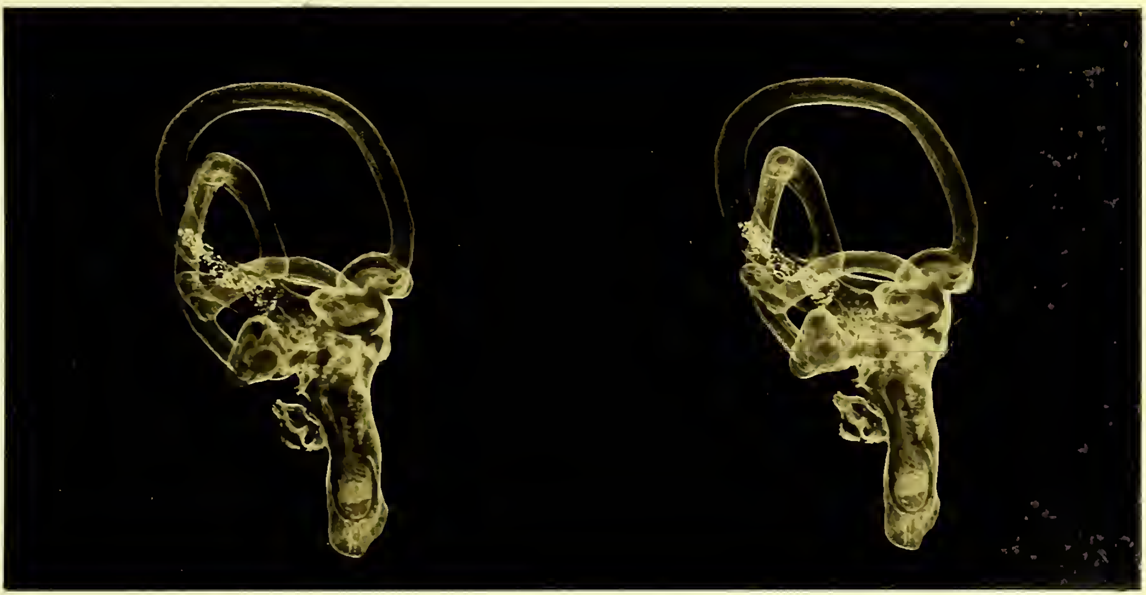
PLATE XXII

THE LEFT MEMBRANOUS LABYRINTH OF THE CAPE GANNET

Sula capensis

× $3\frac{3}{4}$ ca.

The organ is suspended by the superior canal and is viewed from the inner aspect. The superior canal is of the drooping type, but not markedly so. The perilymph space in the canals is not well marked. All the ampullæ are peculiar in shape, the lateral walls bulge outwards so that the structure is more triangular in section than in any other bird. The three non-ampullary limbs of the canals all open into the vestibule together, and there is no common limb to the superior and posterior canals. The horizontal canal takes a sharp bend at the point at which it communicates with the posterior canal. The perilymph recess appears small and flattened, but a portion may have been broken off. The opening of the aqueduct of the cochlea may be seen as a small aperture at the innermost point of the perilymph recess. The inner extremity of the cochlea is bulbous. The whitish speckled appearance in the posterior limb of the superior canal is due to air bubbles in the specimen.



CICONIIFORMES

THE MEMBRANOUS LABYRINTH OF THE CAPE GANNET

Sula capensis

The labyrinth of the cape gannet is amongst the largest of those found in birds. The whole organ measures 17.0 mm. from the uppermost point on the superior canal to the tip of the cochlea.

The *cochlea* has a length of 6.0 mm. from the tip to the anterior margin of the oval window, and the diameter of the tube of the cochlea just in front of the oval window is 2.0 mm.

The *vestibule* measures 4.5 mm. in its longest diameter, and the major axis of the oval window has a length of 2.0 mm.

The *superior canal* measures 7.0 mm. in internal, and 9.5 mm. in external diameter. The height of the vertex of the canal above the vestibule is 8.5 mm., and the diameter of the canal itself at the vertex is rather less than 1.25 mm. The *posterior canal* measures 5.5 mm. in internal, and 8.0 mm. in external diameter. The height of the vertex of the canal above the vestibule is 4.0 mm. and the diameter of the canal itself at the vertex is 1.25 mm. The *horizontal canal* has internal and external diameters of 4.75 mm. and 7.25 mm. respectively. The height of the vertex of the canal above the vestibule is 4.5 mm., and the diameter of the canal itself at the vertex is 1.25 mm.

In all the canals the perilymph space is only moderately well marked, the bird being in this respect unlike the cormorant, to which it is nearly allied. The superior canal may be said to stand midway between the drooping and erect types, but inclines rather to the former. The labyrinths of the two birds, the gannet and cormorant, agree in one noteworthy feature, and are thereby distinguished from those of most birds. There is no common crus to the superior and posterior canals, the three non-ampullary ends of all the canals opening together into the vestibule. This fact is interesting when it is remembered that there is a common crus in the night-heron, which belongs to the same order. It must be pointed out, however, that while the gannet and cormorant belong to the same sub-order, the night-heron does not.

The horizontal canal in the gannet does not lie in one plane throughout, but is bent at its junction with the posterior canal. The ampullæ of all the canals are triangular in section, and are, in this respect, not unlike those of the ostrich. The cristæ acusticæ are complex in their arrangement, but the division into three crests is very slightly marked. There is one otolith of moderately large size in the vestibule, and it is found in the usual place behind and internal to the openings of the ampullæ of the superior and horizontal canals.

The cochlea is almost straight and is of considerable length, but it will be seen that a relatively large portion of the organ is occupied by the lagena ; and at the tip there is a bulging upwards and forwards. The cochlear nerve is of ordinary size where it leaves the stem of the auditory nerve, but very soon it undergoes a rapid contraction. The perilymph recess appears very small in the photograph, but a portion may have been broken off, and its shape and size cannot be reported. The aqueduct of the cochlea opens out of the internal superior angle of the perilymph recess. The tegmentum vasculosum is clearly present in the cochlea of the gannet, but is only moderately developed, the parallel venous spaces numbering only about eighteen or twenty.

A minute otolith is found in the lagena.

PLATE XXIII

THE LEFT MEMBRANOUS LABYRINTH OF THE CORMORANT

Phalacrocorax carbo

× $4\frac{3}{4}$

The organ is suspended by the two limbs of the posterior canal and is rotated counter-clockwise, so that the horizontal canal is almost in a vertical position. The object is seen from the outer aspect and below. All the canals are rather irregular in outline, and the perilymph space is large. The superior canal is of the drooping type. Though the posterior limbs of the superior and horizontal canals come very close together there is no actual channel of communication between them. The cochlea is fairly thick in proportion to its length. The oval window is seen near the vestibular end of the cochlea. The perilymph recess is broken, but a portion of it may be seen. The large lagena is shown clearly with the nerves spreading out to the neuro-epithelium on which lie the otoliths in a saddle-shaped pattern.

CICONIIFORMES

THE MEMBRANOUS LABYRINTH OF THE CORMORANT

Phalacrocorax carbo

Although the cormorant belongs to the same order as the gannet there are some points of difference between the labyrinths of the two birds. That of the cormorant is less regular in shape, and the superior canal is more markedly of the drooping type. There are, moreover, other differences, some of which have already been described (see p. 136).

The whole organ measures 13.5 mm. in its longest diameter from the vertex of the superior canal to the tip of the cochlea. The *cochlea* measures 4.5 mm. from the front of the oval window to the tip, and the diameter of the tube just in front of the oval window is 2.0 mm.

The *vestibule* has a breadth of 3.0 mm. in its longest diameter, and the major axis of the oval window is 1.75 mm. in length. A comparatively small otolith is present in the vestibule in the usual position, just behind and internal to the openings of the ampullæ of the superior and horizontal canals.

The *superior canal* measures 5.0 mm. in internal, and 7.5 mm. in external diameter. The height of the vertex of the canal above the vestibule is 4.0 mm., and the diameter of the canal at the vertex is 1.5 mm. The *posterior canal* measures 4.0 mm. in internal, and 6.25 mm. in external diameter. The height of the vertex of the canal above the vestibule is 2.5 mm., and the diameter of the canal at the vertex is 1.25 mm. The *horizontal canal* measures 4.5 mm. in internal, and 6.5 mm. in external diameter. The height of the vertex of the canal above the vestibule is 3.0 mm., and the diameter of the canal itself at the vertex is 1.5 mm.

Of the three canals the posterior is the smallest and the superior is the longest. In all, the perilymph space is very well marked, and the outlines of the canals themselves are more irregular than in any other bird that has been examined. There is a slight bend in the horizontal canal similar to, but much less pronounced than that which is found in the same canal in the gannet. The ampullæ are cone-shaped in section and unlike those of the gannet; the cristæ acusticæ in the ampullæ are simple.

It is interesting to note that there is no common crus to the posterior limbs of the superior and posterior canals, but the non-ampullary ends of all three canals open into the utricle together. This feature, which is rare in other birds, is found in the gannet, as previously described.

Unfortunately the perilymph recess has been broken off, and cannot therefore be compared with that of other birds. The basilar portion of the cochlea is small, while the lagena on the other hand is very large. In the latter there is a saddle-shaped collection of otoliths. The tegmentum vasculosum is present, but the parallel venous channels are very few, numbering only about ten. The fine striation immediately behind the tegmentum vasculosum in the photograph is produced by the terminal fibres of the cochlear nerve.

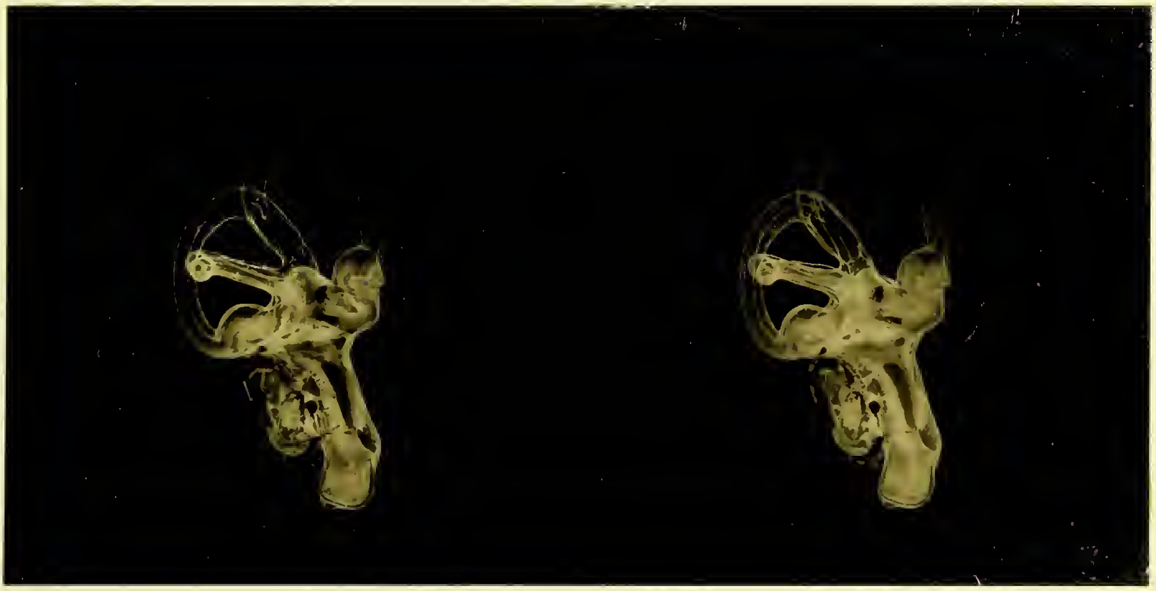
PLATE XXIV

THE LEFT MEMBRANOUS LABYRINTH OF THE NIGHT-HERON

Nycticorax griseus

× 4 circa

The organ is suspended by the superior canal and is viewed from behind and from the inner aspect. The perilymph space is well marked in all the canals. The superior canal inclines to the drooping type, and there is no communication between the posterior limbs of the superior and horizontal canals. The common crus of the posterior and superior canals is very short. A flat triangular otolith (dark) is seen on the floor of the utricle. The cochlea is relatively thick and is bulbous at the extremity. The perilymph recess is large and oval in shape, and hæmorrhages may be seen in its walls. The aqueduct of the cochlea curves upwards on the posterior surface of the perilymph recess. The position of the aqueduct of the vestibule is indicated by a small irregular mass of pigment immediately below and in front of the common crus of the superior and posterior canals.



CICONIIFORMES

THE MEMBRANOUS LABYRINTH OF THE NIGHT-HERON

Nycticorax griseus

The labyrinth of the night-heron measures 13.0 mm. in its greatest length from the vertex of the superior canal to the tip of the cochlea. The length of the *cochlea* from the front of the oval window to the tip is 4.0 mm., and the diameter of the cochlea at the level of the oval window is 1.5 mm.

The *vestibule* measures 3.5 mm. in its longest diameter, and the major axis of the oval window is rather more than 1.5 mm. in length. A flat triangular otolith is present on the floor of the utricle about the middle, and lies in the horizontal plane. A small collection of pigment is present in the vestibule, or rather along the aqueduct.

The *superior canal* is regularly curved and is of the drooping type. It measures 5.0 mm. in internal, and 7.0 mm. in external diameter. The height of the vertex of the canal above the vestibule is 5.5 mm., and the diameter of the canal at the vertex is 1.0 mm. The internal and external diameters of the *posterior canal* are 3.75 mm. and 5.25 mm. respectively. The height of the vertex of the canal above the vestibule is 3.5 mm., and the diameter of the canal at the vertex is 1.0 mm. The *horizontal canal* measures 4.5 mm. in internal, and

6.0 mm. in external diameter. The height of the vertex of the canal above the vestibule is 3.5 mm., and the diameter of the canal at the vertex is 1.0 mm. The cristæ acusticæ in the ampullæ are simple.

The posterior limb of the superior canal does not descend very low, and there is therefore no contact between the superior and horizontal canals in this region. The usual communication between the horizontal and posterior canals is present. Each of the canals lies in its own plane throughout, and the perilymph space is well marked.

The perilymph recess is comparatively large and is oval in shape. A small twig from the nerve to the posterior ampulla crosses over to the perilymph recess at its most external point. The aqueduct of the cochlea arises from the posterior surface of the perilymph recess and, curving upwards and outwards in contact with that cavity, opens within the cranium at the level of, and just behind the middle of the posterior surface of the cochlea. The cochlea is slightly bulbous at the extremity, and the lagena is large and spade-shaped.

The tegmentum vasculosum is moderately developed, the parallel venous spaces numbering about twenty-seven.

II.

10

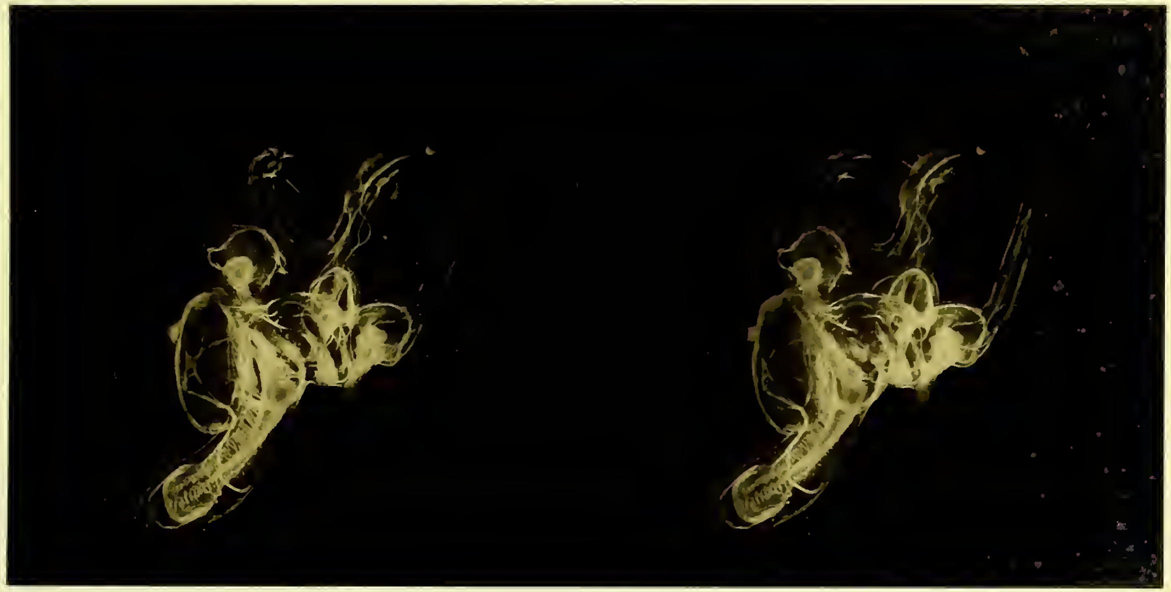
PLATE XXV

THE LEFT MEMBRANOUS LABYRINTH OF THE COMMON DUCK

Anas boscas

× $5\frac{3}{4}$

The organ is suspended by the horizontal canal and is rotated clockwise very considerably. It is viewed from above and behind. The superior canal is of a marked drooping type and is broken at the vertex ; it is elliptical in shape. The perilymph space is not very large in the canals, and there is no communication between the posterior limbs of the horizontal and superior canals, but the usual communication between the horizontal and posterior canals is present. The cochlea is fairly well curved and is slightly bulbous at the extremity. The perilymph recess is fairly large and is oval in shape. The tegmentum vasculosum is well seen, and it will be observed that it extends into the lagena.



ANSERIFORMES

THE MEMBRANOUS LABYRINTH OF THE COMMON DUCK

Anas boscas

The common duck may be taken as a good example of the order of anseriformes.

The superior canal is of a marked drooping type, and the cochlea is moderately well developed.

The whole organ measures 11.0 mm. from the uppermost point on the vertex of the superior canal to the tip of the cochlea. The *cochlea* has a length of 4.0 mm. from the tip to the anterior margin of the oval window, and the diameter of the organ opposite the oval window is 1.75 mm.

The *vestibule* measures 4.5 mm. in its longest diameter. The length of the major axis of the oval window was not taken.

The *superior canal* has internal and external diameters of 3.0 mm. and 4.5 mm. respectively. The height of the vertex of the canal above the vestibule is 6.0 mm., and the diameter of the canal itself at the vertex is 1.0 mm. The *posterior canal* measures 3.5 mm. in internal, and 5.0 mm. in external diameter. The height of the vertex of the canal above the vestibule is 4.0 mm., and the diameter of the canal itself at the vertex is 1.0 mm. The *horizontal canal* measures 3.5 mm.

in internal, and 5.0 mm. in external diameter. The height of the vertex of the canal above the vestibule is 3.0 mm., and the diameter of the canal itself at the vertex is 1.0 mm.

The superior canal of the duck, as already noted, is of a very marked drooping type. This canal is also in the form of a narrow ellipse, as may be seen from the photograph, and, as is usually the case in this type, the posterior limb of the canal does not come far down ; hence there is no communication between the posterior limb of this canal and that of the horizontal. There is, of course, the usual communication between the posterior and horizontal canals. The perilymph space is present in all the canals to a moderate extent, and the ampullæ are almost hemispherical in shape. The cristæ acusticæ of the ampullæ are simple. A comparatively small otolith is found in the vestibule, in the usual position, immediately behind and internal to the ampullæ of the horizontal and superior canals.

The cochlea is of moderate length and is fairly well-curved. The perilymph recess is large, and, when viewed from above, is oval in shape ; the aqueduct of the cochlea runs upwards along its posterior border rather further out than is usually the case. The lagena is saddle-shaped and there are a few otoliths scattered along its innermost portion. The tegmentum vasculosum is well-developed in the duck, and may be seen in the photograph right up into the lagena.

Pigment is not found in quantity sufficient to be recognised by the naked eye.

Literature.—Huschke, *Loc. cit.* Ebner, *Ber. d. naturwissensch.-med. Verein in Innsbrück*, dritte Jahrgang, 1872. Retzius, *Op. cit.*

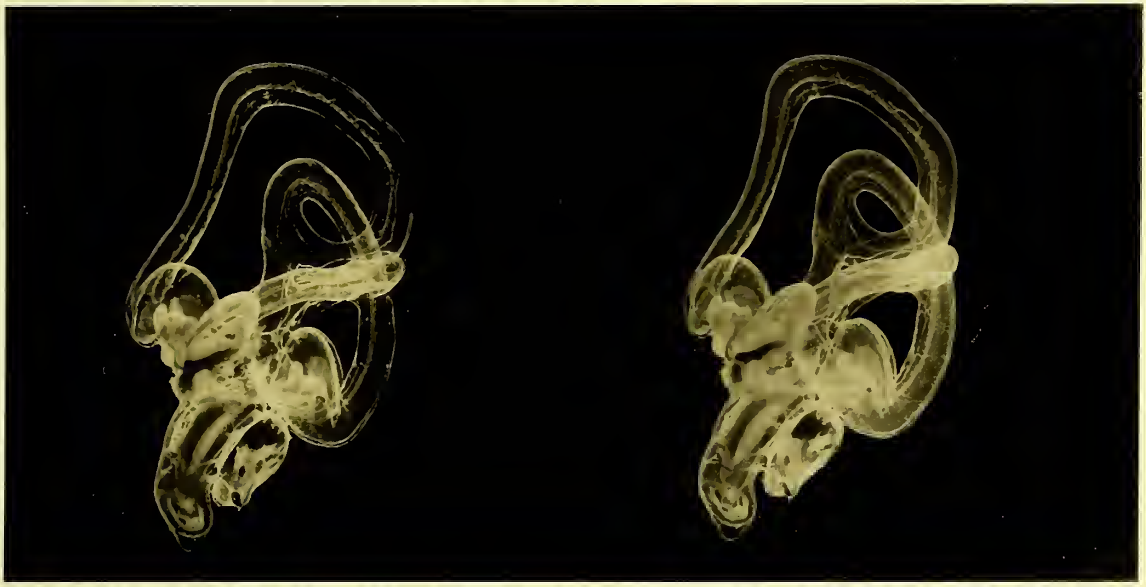
PLATE XXVI

THE RIGHT MEMBRANOUS LABYRINTH OF THE COMMON BUZZARD

Buteo vulgaris

× $4\frac{1}{2}$

The organ is suspended by the superior canal and is viewed from the inner aspect and behind. The superior canal is of the erect type and the perilymph space is well developed in the canals. The ampullæ are relatively large, and it will be noticed that the cristæ acusticæ are complex, as described in the text. The horizontal canal has the usual communication with the posterior canal, and in addition has a communication with the superior canal near the posterior termination of the latter. The otolith of the vestibule is comparatively large and appears as a dark irregular mass internal to and behind the ampullæ of the superior and horizontal canals. The cochlea is of moderate size, and the perilymph recess is oval in shape, with the aquæductus cochleæ curving upwards over its inner wall. A vein is seen coming from the helicotrema, curving over the upper surface of the cochlea, passing over to the perilymph recess and leaving the labyrinth at the same spot as the aquæductus cochleæ. This vein corresponds to that which is found in mammals leaving the cochlea along with the aquæductus cochleæ (vol. i. Plate ii.). A small collection of otoliths is seen in the lagena.



FALCONIFORMES

THE MEMBRANOUS LABYRINTH OF THE COMMON BUZZARD

Buteo vulgaris

The labyrinth of the buzzard is large in proportion to the size of the bird owing to the relatively great development of the semicircular canals.

The whole organ measures 15.5 mm. in its longest diameter from the vertex of the superior canal to the tip of the cochlea. The *cochlea* measures 4.5 mm. in length from the front of the oval window to the tip, and the diameter opposite the oval window is 2.0 mm.

The *vestibule* measures 4.5 mm. in its longest diameter, and the major axis of the oval window is 2.0 mm. in length. A large otolith is found in the utricle immediately behind and internal to the ampullæ of the superior and horizontal canals. The otolith is flat and lies almost in the horizontal plane.

The *superior canal* measures 5.25 mm. in internal, and 7.25 mm. in external diameter. The height of the vertex above the vestibule is 7.25 mm., and the diameter of the canal itself at the vertex is 1.5 mm.

The *posterior canal* measures 6.0 mm. in internal, and 9.0 mm. in external diameter. Thus, at first sight, it would appear that the posterior is larger than the superior canal, but in reality this is not so, since the height of the vertex of the canal above the vestibule is only 4.5 mm. The diameter of the canal at the vertex is 1.5 mm. The *horizontal canal* measures 7.0 mm. in internal, and 9.5 mm. in external diameter. The height of the vertex of the canal above the vestibule is 4.5 mm., and the diameter of the canal at the vertex is 1.5 mm. Thus the superior is the largest of the canals, and the posterior the smallest; but the differences in size of the three canals are less than is usual among birds. The superior canal is of the erect type, and the anterior superior curve of that canal is almost angular. The perilymph space is well marked in all the canals. The horizontal canal has two communications with the others. One of these is the usual one about its middle with the posterior canal, and the second is the much less common channel between the posterior limbs of the superior and horizontal canals. As is nearly always the case when this opening exists, the posterior limb of the superior canal reaches a low level, and is actually turning upwards again before it joins the posterior canal to form the common crus.

The ampullæ are relatively very large, and the cristæ acusticæ are complex.

The cochlea of the buzzard is relatively small, and the same is true of the perilymph recess, which is elliptical in shape. There are two little tongue-like projections at the tip of the cochlea and a few small otoliths are found in the lagena.

The ductus perilymphaticus opens out of the lower part of the internal posterior wall of the perilymph recess and, curving upwards in close contact with that cavity, opens into the cranial cavity a fraction of a millimetre behind the middle of the posterior wall of the cochlea.

Pigment is not present in the labyrinth of the buzzard, at least in sufficient quantity to be recognised by the naked eye.

The labyrinth of the sparrowhawk was also examined, but it differs so little from that of the buzzard that no description need be given. The measurements are found in Table II.

LITERATURE.—Huschke, *Loc. cit.* Deiters, *Arch. f. Anat., Physiolog. u. wissensch. Med.* 1860. Retzius, *Op. cit.*

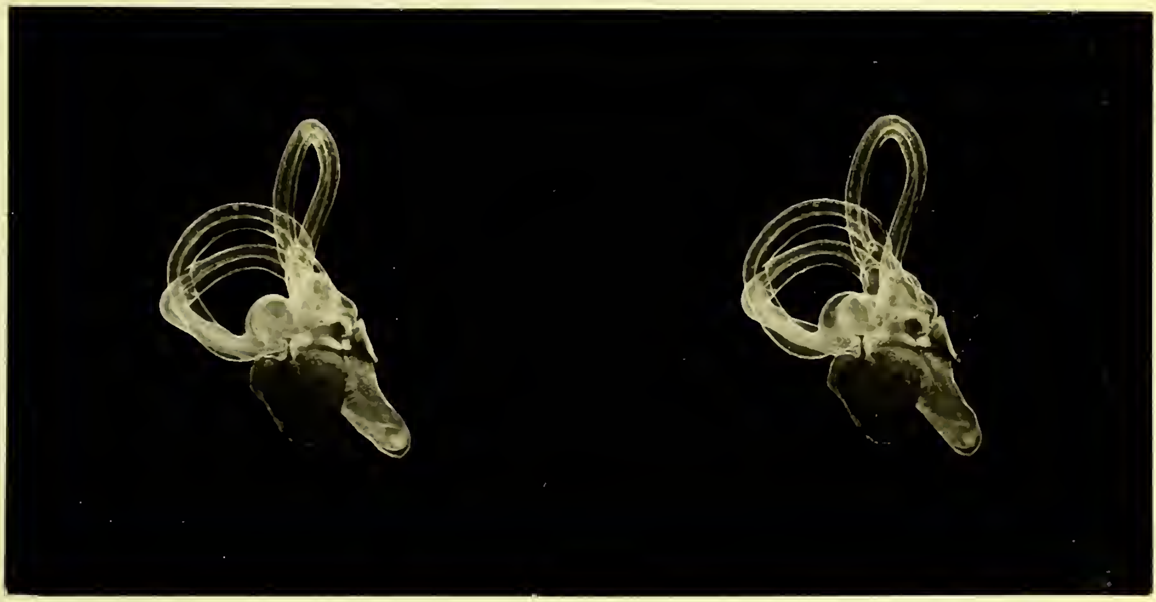
PLATE XXVII

THE LEFT MEMBRANOUS LABYRINTH OF THE GREAT TINAMOU

Rhynchotus rufescens

× $4\frac{3}{4}$

The organ is suspended by the superior canal and is viewed from behind. The perilymph space in all the canals is very well marked. The superior canal is of the drooping type, but is not elliptical in shape. There is the usual channel of communication between the posterior and horizontal canals. There is no common limb to the posterior and superior canals, the non-ampullary ends of all the canals opening into the vestibule close together. A pigmented nerve twig is seen passing from the ampulla of the posterior canal to the perilymph recess. The cochlea is relatively small and a band of scattered pigment runs along its upper surface. The perilymph recess is very large, is roughly pyramidal in shape and its walls contain a large amount of pigment.



TINAMIFORMES

THE MEMBRANOUS LABYRINTH OF THE GREAT TINAMOU

Rhynchotus rufescens

Anatomists have found difficulty in assigning to this order its true relationship to other orders of birds, some considering it to be allied to the ratitæ, while others, among whom is Gadow, look upon it as an order with affinities to the gallinaceous birds. So far as the labyrinth is concerned, it must be admitted that the organ is rather more like that of the ratitæ than the gallinaceous birds. In both orders the superior canal is of the drooping type, but the ellipse formed by the canal in the tinamou is much more like those in the ostrich and apteryx than those in the domestic fowl and the grouse. One feature, however, the tinamou has in common with the galliformes, that being the communication between the posterior and horizontal canals, a characteristic which is wanting in the ostrich and the apteryx. But even this evidence of relationship between the tinamous and the gallinaceous birds is considerably weakened by the fact that this communication between the two canals is also found in the rhea, which is undoubtedly a ratite bird; and it is of further interest to note that the rhea and the tinamou are confined to the southern parts of the New World. The rich deposit of pigment in the labyrinth of the tinamou also may have a certain bearing upon the relationship of this order with the ratitæ, although it must be remembered that in the apteryx pigment is very scanty.

The labyrinth of the tinamou measures 9.5 mm. from the tip of the cochlea to the vertex of the superior canal. The *cochlea* has a length of 2.5 mm. from the front of the oval window to the tip, and the diameter of the organ opposite the oval window is 1.5 mm.

The diameter of the *vestibule* is 2.5 mm., and the major axis of the oval window has a length of 1.0 mm.

The *superior canal* measures 3.75 mm. in internal, and 5.25 mm. in external diameter. The height of the vertex of the canal above the vestibule is 5.5 mm., and the diameter of the canal itself at the vertex is rather less than 1.0 mm. The *posterior canal* has internal and external diameters of 3.0 mm. and 4.5 mm. respectively. The height of the vertex of the canal above the vestibule is 2.75 mm., and the diameter of the canal itself at the vertex is 1.0 mm. The *horizontal canal* measures 3.5 mm. in internal, and 5.25 mm. in external diameter. The height of the vertex of the canal above the vestibule is 2.75 mm., and the diameter of the canal at the vertex is 1.0 mm.

The superior canal is of the drooping type, but the ellipse formed by the canal is not a narrow one. The posterior limb of the superior canal reaches low, but not sufficiently so to form a communication with the horizontal canal. The usual communication between the posterior and horizontal canals is present. The non-ampullary ends of the three canals open into the vestibule together, in a manner similar to that which is found in the gannet. The perilymph space is very well marked in all the canals, and the ampullæ are rather large; but the cristæ acusticæ are simple, there being only one crest on that portion of the neuro-epithelium which lies on the floor of the ampulla. The nerve to the posterior ampulla gives off a small twig which passes across to the perilymph recess, as is the case in many birds. There is pigment on this twig similar to that which is found in the same structure in the ostrich. A small otolith is present in the utricle.

The cochlea of the tinamou is rather small, but is relatively larger than those of the ostrich and rhea, and is rather more sharply curved. The perilymph recess is unlike those of other birds, being pear-shaped. It is, moreover, thickly covered with black pigment, such as is found in the ostrich and, to a less extent, in the rhea. The aqueduct of the cochlea is extremely narrow and short, leaving the perilymph recess at the inner and upper extremity of the latter, and opening almost immediately into the cranial cavity. It is similar to that of the ostrich and common fowl, in that it is relatively small and does not curve over the posterior wall of the perilymph recess, as is commonly the case in birds. A band of scattered pigment is present on the upper wall of the cochlea, and towards the tip of the organ this band passes over to the anterior border. A small otolith is found in the lagena.

The tegmentum vasculosum is present in the tinamou, but the number of parallel venous spaces is small, numbering about fifteen.

PLATE XXVIII

THE RIGHT MEMBRANOUS LABYRINTH OF THE COMMON FOWL

Gallus domesticus

× 5 ca.

The organ, viewed from the inner aspect, is suspended by the superior canal and is rotated counter-clockwise to an extent of nearly 60°, so that the horizontal canal lies in a plane passing downwards and to the left. The superior canal is of a pronounced drooping type and its ellipse is narrow. The perilymph space is smaller in this labyrinth than in that of any other bird. The cristæ of the ampullæ are simple. The inner portion of the shaft of the columella may be seen as a short rod to the left of the beginning of the cochlea, and, if it be traced towards the latter, the disc-shaped footplate may be seen fitting into the oval window. The lagena is of moderate size and rounded at the end. On the posterior and inferior aspect of the cochlea is the perilymph recess and from the inner and upper corner of this cavity the aqueduct of the cochlea may be seen leaving it in a manner similar to that of the ostrich, tinamou and thrush.

GALLIFORMES

THE MEMBRANOUS LABYRINTH OF THE COMMON FOWL

Gallus domesticus

The domestic fowl belongs to the group of birds in which the labyrinth is possessed of a drooping type of superior canal.

The whole labyrinth measures 12.5 mm. in extreme length from the vertex of the superior canal to the tip of the cochlea. The *cochlea* measures rather more than 3.75 mm. in length from the tip to the anterior margin of the oval window, and the diameter of the tube of the cochlea opposite the oval window is 1.5 mm. Thus the organ is somewhat narrow.

The *vestibule* measures 3.5 mm. in its longest diameter, and a rather large flat otolith is present in the utricle immediately internal to and behind the openings of the superior and horizontal ampullæ.

The *superior canal* measures 3.75 mm. in internal, and 4.5 mm. in external diameter. The height of the vertex of the canal above the vestibule is 6.25 mm., and the diameter of the canal at the vertex is rather less than 1.0 mm. The *posterior canal* has internal and external diameters of 4.0 mm. and 5.0 mm. respectively. The height of the vertex of the canal above the vestibule is rather more than 3.5 mm., and the diameter of the canal itself at the vertex is 1.0 mm. The *horizontal canal* measures 4.75 mm. in internal, and 6.0 mm. in external diameter. The height of the vertex of the canal above the vestibule is rather more than 3.5 mm., and the diameter of the canal itself at the vertex is 1.0 mm.

The superior canal is of a marked drooping type, and the ellipse formed by the canal is narrow and regular in outline. The perilymph space is not at all well marked in the canals and is nearly obliterated at one portion of the superior canal. The cristæ acusticæ of the ampullæ are simple : that is to say, there is only one crest in the neuro-epithelium on the floor of the ampulla.

The cochlea is rather short but is well-curved, and the tip is rounded. A saddle-shaped otolith is present in the lagena. The perilymph recess is oval when viewed from above and within, and it receives a twig from the nerve to the posterior ampulla. The aqueduct of the cochlea arises at the upper and inner extremity of the perilymph recess, and after a very short course opens into the cranial cavity immediately behind the middle of the cochlea. It is a fine tube accompanied by a vein and resembles that of the ostrich, tinamou and thrush, in that it arises high up in the perilymph recess and is very short and narrow.

The ampullæ are only of moderate size, and, while there is the usual communication between the posterior and horizontal canals, there is none between the horizontal and superior canals. Pigment is not found in this labyrinth, at least in quantity sufficient to be discovered by the naked eye.

LITERATURE.—Deiters, *Loc. cit.* 1860. Hasse, *De cochlea Avium*, 1866. Ebner, *Loc. cit.* 1872. Retzius, *Op. cit.*

II.

II

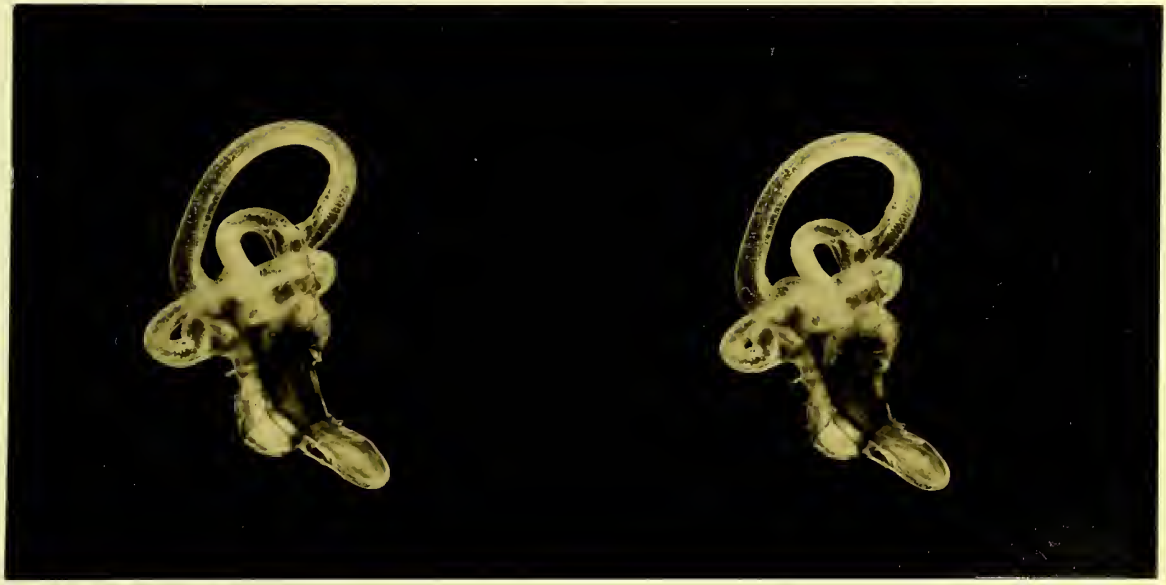
PLATE XXIX

THE RIGHT MEMBRANOUS LABYRINTH OF THE RED GROUSE

Lagopus scoticus

× 5

The organ is suspended by the superior canal and is viewed from the inner aspect and in front; it is also rotated counter-clockwise a little. The canals as a whole are relatively thicker than in the common fowl, and the perilymph space is well marked. There is the usual communication between the posterior and horizontal canals, but not between the superior and horizontal. The superior canal is distinctly of the drooping type and is elliptical in shape. The cochlea is fairly well curved and is very similar to that of the common fowl. The perilymph recess is of moderate size.



GALLIFORMES

THE MEMBRANOUS LABYRINTH OF THE RED GROUSE

Lagopus scoticus

In its general appearance the labyrinth of the grouse resembles that of the common fowl, and there are no features of very special interest. The labyrinth as a whole is perhaps rather small in proportion to the size of the bird.

The organ measures 10.0 mm. in length from the vertex of the superior canal to the tip of the cochlea. The *cochlea* measures 3.5 mm. from the front of the oval window to the tip, and the diameter of the organ at its origin is 1.25 mm.

The *vestibule* measures 3.5 mm. in its longest diameter, and the major axis of the oval window is 1.5 mm. in length.

The *superior canal* measures 4.0 mm. in internal, and 5.5 mm. in external diameter. The height of the vertex of the canal above the vestibule is 3.0 mm., and the diameter of the canal itself at the vertex is 0.75 mm. The internal diameter of the *posterior canal* is 3.0 mm., and the external is 4.25 mm. The height of the vertex of the canal above the vestibule is 2.75 mm., and the diameter of the canal itself at the vertex is 0.75 mm. The *horizontal canal* measures 3.25 mm. in internal, and 5.0 mm. in external diameter. The height of the vertex of the canal above the vestibule is

2.25 mm., and the diameter of the canal itself at the vertex is 0.75 mm.

The perilymph space is fairly well marked in all the canals. The superior canal is of the drooping type and elliptical in shape, but the ellipse is not so narrow as in the labyrinth of the duck or the common fowl. There is no communication between the posterior limbs of the horizontal and superior canals, but the usual one between the horizontal and posterior canals is present. The canals are proportionately thicker than in the common fowl.

The cristæ acusticæ of the ampullæ are complex. No pigment is found in the labyrinth.

The cochlea is not bulbous at the tip, and the lagena is large relative to the rest of the organ. The perilymph recess is of moderate size, and when viewed from the inner aspect, appears to be roughly oval in shape.

PLATE XXX

THE LEFT MEMBRANOUS LABYRINTH OF THE CROWNED CRANE

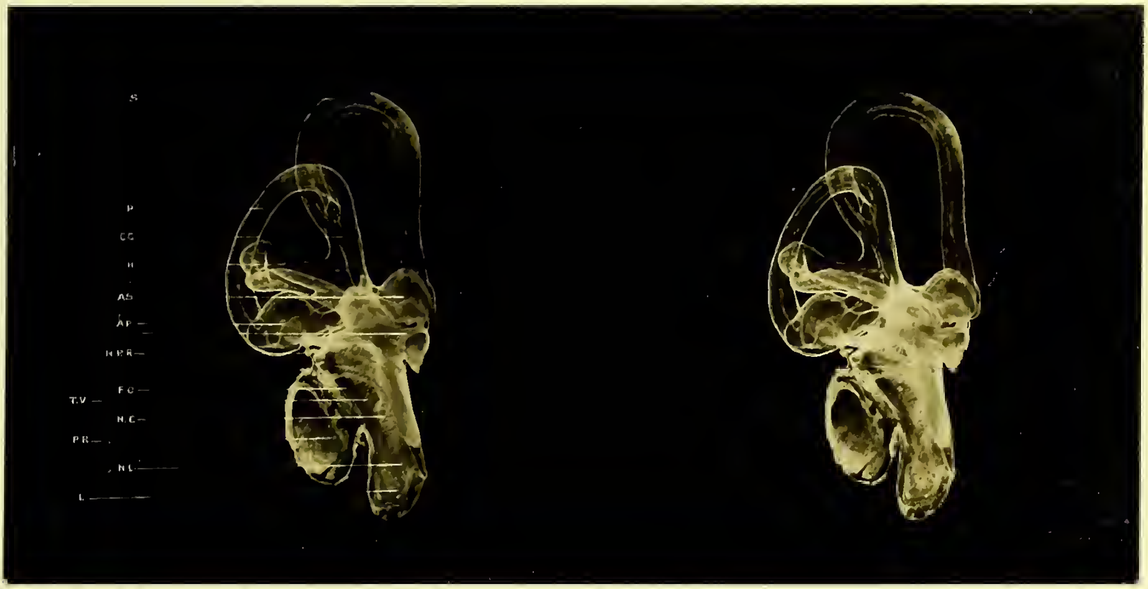
Balearica pavonina

× $3\frac{3}{4}$

The organ is suspended by the superior canal and is viewed from the inner aspect, and behind. The letters indicate the different structures.

S.	Superior canal.
P.	Posterior canal.
C. C.	Common crus of superior and posterior canals.
H.	Horizontal canal.
A. S.	Ampulla of superior canal.
A. P.	Ampulla of posterior canal.
O.	Otolith.[1]
N. P. R.	Nerve twig to perilymph recess.
F. O.	Fenestra ovalis.
T. V.	Tegmentum vasculosum.
N. C.	Nerve to cochlea.
P. R.	Perilymph recess.
N. L.	Nerve fibres radiating out to the lagena.
L.	Lagena.

[1] The line pointing to the otolith in the photograph should be one millimetre higher.


S
P
CC
H
AS
AP
H P R
F C
T.V
N.C
P R
N L
L

GRUIFORMES

THE MEMBRANOUS LABYRINTH OF THE CROWNED CRANE

Balearica pavonina

The labyrinth of the crane is comparatively large, measuring 15.0 mm. from the vertex of the superior canal to the tip of the cochlea. The *cochlea* has a length of 4.5 mm. from the tip to the anterior margin of the oval window. The diameter of the tube of the cochlea opposite the oval window is 2.0 mm.

The *vestibule* measures 3.5 mm. in its longest diameter, and the major axis of the oval window has a length of 1.5 mm. A small otolith is present in the utricle in the usual place immediately internal to and behind the openings of the ampullæ of the superior and horizontal canals.

The *superior canal* measures 6.0 mm. in internal, and 8.0 mm. in external diameter. The height of the vertex of the canal above the vestibule is 6.5 mm., and the diameter of the canal itself at the vertex is 1.25 mm. The *posterior canal* has internal and external diameters of 4.75 mm. and 6.5 mm. respectively. The height of the vertex of the canal above the vestibule is 3.25 mm., and the diameter of the canal itself at the vertex is rather more than 1.0 mm. The *horizontal canal* measures 4.5 mm. in internal, and 6.5 mm. in external diameter. The height of the vertex of the canal above the vestibule is 3.0 mm., and the diameter of the canal itself at the vertex is 1.0 mm.

The points of chief interest in the labyrinth of the crane are as follows. The superior canal is distinctly of the upright type, and the perilymph space is well marked in all the canals. Although this canal is of the erect type, the posterior limb does not descend very far, so that there is no communication between it and the same limb of the horizontal canal, as in the pigeon and the buzzard. The usual communication between the posterior and horizontal canals is present. The cristæ acusticæ of the ampullæ are complex, there being three crests in that portion which lies on the floor of the ampulla. The fan-shaped structures on the lateral walls of the ampullæ are not so well marked as in many birds, such as the buzzard, but the ampullæ as a whole are fairly large. The nerve to the posterior ampulla gives off a small twig which passes across to the perilymph recess.

The cochlea is of average dimensions, and the lagena forms a fairly large portion of the organ, but it is not noticeably bulbous. Three very small otoliths are to be seen in the lagena. The perilymph recess is rather large, and is oval when viewed from above and behind. A minute trace of pigment is present on the inner and upper wall of the perilymph recess.

The tegmentum vasculosum is fairly well developed in the crane, the parallel venous channels numbering about thirty-five.

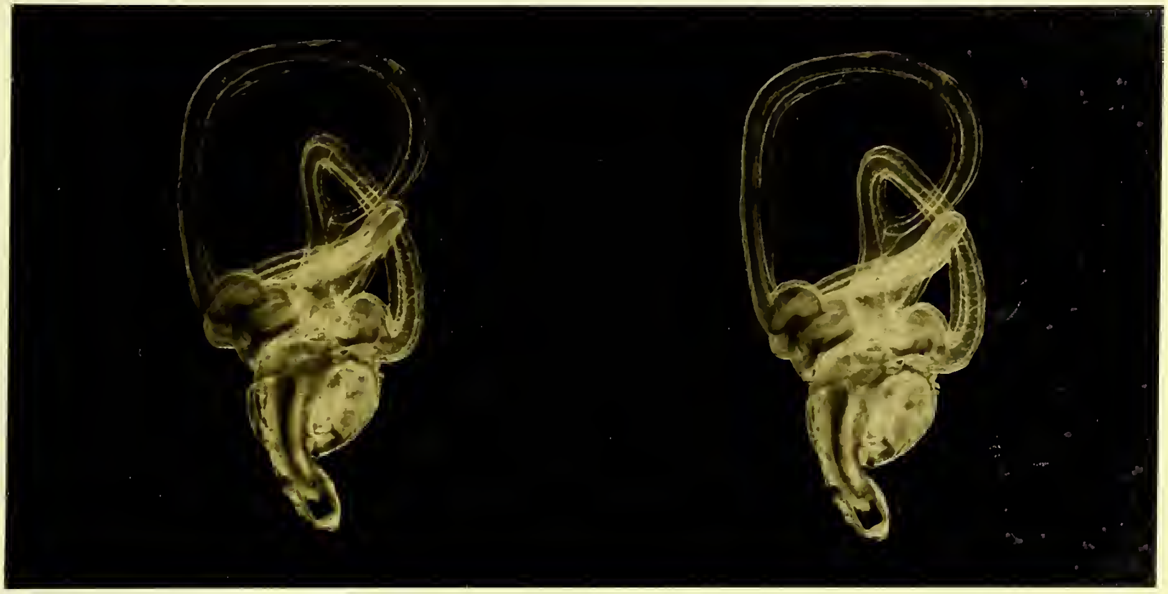
PLATE XXXI

THE RIGHT MEMBRANOUS LABYRINTH OF THE CROWNED PIGEON

Goura coronata

× 5

The organ is suspended by the superior canal and is viewed from the inner aspect and behind; it is rotated counter-clockwise to a slight extent. The superior canal is of the upright type. There is a communication between the horizontal and superior, in addition to the usual one between the horizontal and posterior canals. The recessus utriculi is seen between the superior and horizontal ampullæ with a flat otolith lying on its floor. The cristæ in the ampullæ are complex. The cochlea is not very large, and in the lagena is a saddle-shaped otolith. The perilymph recess is large, and the aqueduct of the cochlea is seen rising from its inner wall and curving upwards for a short distance in contact with it. The horizontal canal dips slightly downwards about the middle.



CHARADRIIFORMES

THE MEMBRANOUS LABYRINTH OF THE CROWNED PIGEON

Goura coronata

The labyrinth of this order of birds shows similarity in many respects to that of the falconiformes, and still more to that of the passeriformes. Thus the superior canal is of the erect type, and there is a communication between the posterior limbs of the horizontal and superior canals—a peculiarity also found in the orders just mentioned. The cochlea is rather small, and the perilymph recess is almost identical in shape with that of the buzzard. Furthermore, the cristæ acusticæ in the ampullæ are complex, possessing three crests, as in the falconiformes and passeriformes. Indeed, the labyrinths of these orders show far more similarity than exists in many cases between two species in many other orders. Thus, there is more likeness between the labyrinths of the buzzard and the pigeon than between those of the cormorant and the night-heron, though these two belong to the same order.

The labyrinth of the crowned pigeon measures 13.0 mm. in extreme length from the vertex of the superior canal to the tip of the cochlea. The length of the *cochlea* from the tip to the front of the oval window is rather more than

4.5 mm., and the diameter of the tube of the cochlea opposite the oval window is 1.5 mm.

The *vestibule* measures 3.5 mm. in its longest diameter, and the major axis of the oval window 1.5 mm. There are no otoliths in the vestibule of a size sufficient to be recognised by the unaided eye.

The *superior canal* measures 5.25 mm. in internal, and 7.5 mm. in external diameter. The height of the vertex of the canal above the vestibule is 6.75 mm., and the diameter of the canal itself at the vertex is 1.0 mm. The *posterior canal* has internal and external diameters of 4.0 mm. and 6.5 mm. respectively. The height of the vertex of the canal above the vestibule is 3.5 mm., and the diameter of the canal itself at the vertex is 1.0 mm. The *horizontal canal* measures 5.0 mm. in internal, and 7.0 mm. in external diameter. The height of the vertex of the canal above the vestibule is 2.5 mm., and the diameter of the canal itself at the vertex is 1.0 mm.

The superior canal is distinctly of the upright type, being more pronounced in this respect than even that of the buzzard. As in the latter bird, there is a communication between the posterior limbs of the horizontal and superior canals, but in the pigeon the posterior limb of the superior canal does not come quite so low as in the buzzard. The superior is the largest and the posterior the smallest of the canals, and in all, the perilymph space is well marked. There is a slight curve downwards in the middle of the horizontal canal.

The perilymph recess is fairly large and is oval when viewed from above. The aqueduct of the cochlea leaves the perilymph space on the inner wall of the latter cavity, and is thus situated nearer to the cochlea than is usual in birds. It curves upwards and slightly backwards in close contact with the perilymph recess and opens into the cranial cavity a little distance behind the middle of the cochlea.

The cochlea is rather small, but this is owing to the comparatively small lagena, the basilar portion being well developed and the parallel venous spaces of the tegmentum vasculosum being fairly numerous. A large saddle-shaped otolith is found in the lagena.

Pigment is not present in the labyrinth in sufficient quantity to be seen by the unaided eye.

Besides the labyrinth of the crowned pigeon, that of the rock, or domestic, pigeon was examined. It differed from that of the former only in the matter of size.

LITERATURE.—Huschke, *Loc. cit.* Deiters, *Loc. cit.* Hasse, *Loc. cit.* Ebner, *Loc. cit.* Paul Meyer, *Etudes histolog. sur le labyrinthe et plus spécial. sur le limaçon chez les reptiles et les oiseaux*, Strasburg, 1876. Retzius, *Op. cit.*

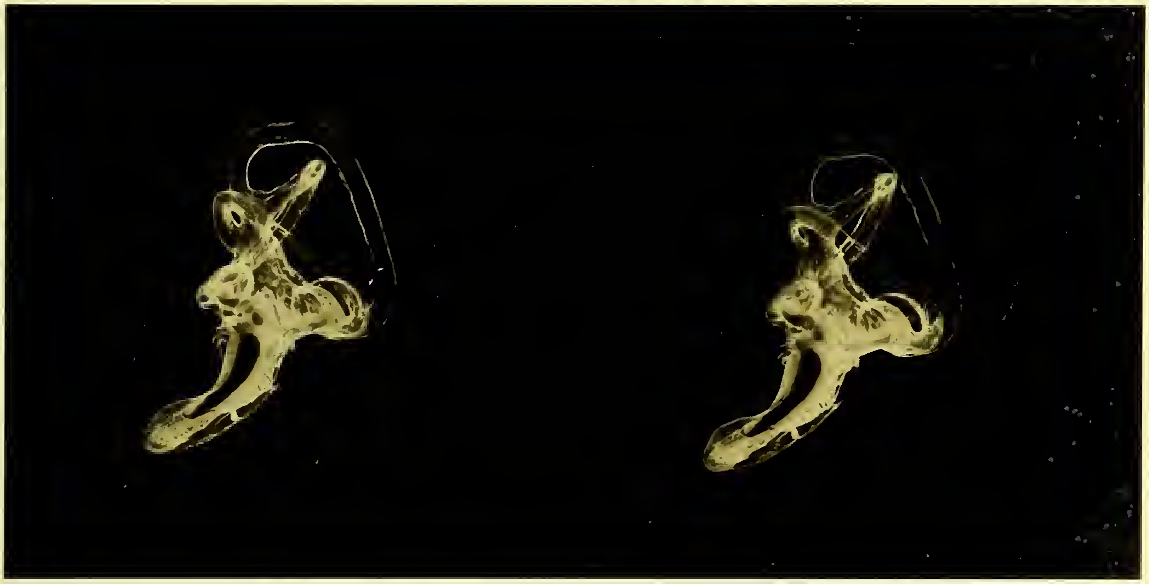
PLATE XXXII

THE LEFT MEMBRANOUS LABYRINTH OF THE SLENDER-BILLED COCKATOO

Licmetis nasica

× 4

The organ is suspended by the superior canal, but is rotated clockwise and is viewed from the inner aspect and above. The perilymph space in the canals is not very well marked. The superior canal is of a pronounced drooping type, and there is no channel of communication between the superior and horizontal canals, but the usual communication between the horizontal and posterior canals is present. The cochlea is relatively long and rather more curved than in many birds. The perilymph recess appears to be very small, but it is possible that a portion may have been broken off.



CUCULIFORMES

THE MEMBRANOUS LABYRINTH OF THE SLENDER-BILLED COCKATOO

Licmetis nasica

The labyrinth of this representative of the parrot tribe of birds measures 11.5 mm. in length from the vertex of the superior canal to the tip of the cochlea. The length of the *cochlea* from the tip to the front of the oval window is 5.0 mm., and the diameter of the tube at its beginning is 2.0 mm.

The *vestibule* measures 3.0 mm. in its longest diameter, and the major axis of the oval window has a length of 1.5 mm. No otoliths of a size sufficient to be recognised by the naked eye are present in the vestibule.

The *superior canal* measures 4.5 mm. in internal, and 6.5 mm. in external diameter. The height of the vertex of the canal above the vestibule is 3.75 mm., and the diameter of the canal at the vertex is 0.75 mm. The *posterior canal* has internal and external diameters of 4.5 mm. and 6.0 mm. respectively. The height of the vertex of the canal above the vestibule is 3.5 mm., and the diameter at the vertex is 0.75 mm. The *horizontal canal* measures 4.5 mm. in internal, and 6.5 mm. in external diameter. The height of the vertex of the canal above the vestibule is 2.75 mm., and the diameter at the vertex is 0.75 mm.

The perilymph space in the canals is only of moderate size. The superior canal is distinctly of the drooping type, but it is different from that of other birds in respect to the fact that there is a very distinct angle at its highest point.

The perilymph recess appears to be very small, but possibly a portion has been broken off in the specimen from which the photograph is taken. The course of the aqueduct of the cochlea could not be traced in the labyrinth of the cockatoo.

The cochlea is relatively long, and the nerve to that organ is particularly large. The tegmentum vasculosum is well developed, the parallel venous spaces being numerous. Altogether the basilar portion of the cochlea appears to be well developed, though, perhaps, not to quite such an extent as in the thrush. The lagena is of moderate size, and there are no otoliths in it of a size sufficient to be recognised by the unaided eye.

Pigment is not present in the labyrinth of the cockatoo in sufficient quantity, at any rate, to be recognised by the unaided eye.

LITERATURE.—Denker, *Das Gehörorgan u. Sprechwerkzeuge d. Papageien.* F. Bergmann, Wiesbaden, 1907.

11.

12

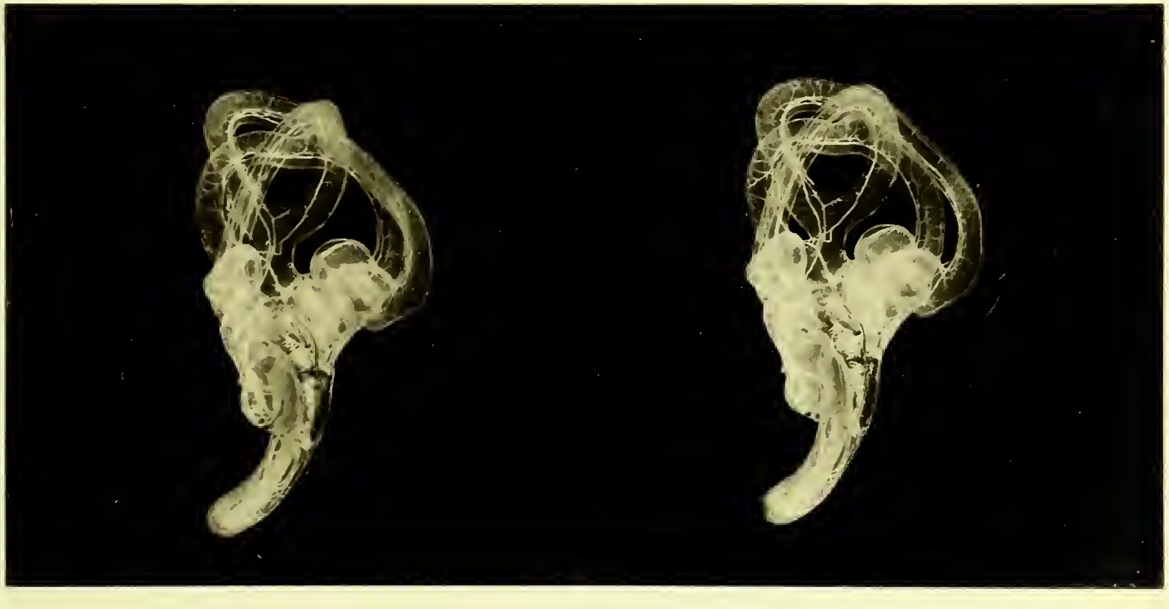
PLATE XXXIII

THE RIGHT MEMBRANOUS LABYRINTH OF THE BURROWING OWL

Speotyto cunicularia

× 4¾

The organ is suspended by the posterior canal and is viewed from below and in front. The veins in the canals are distended with blood. The perilymph space in the canals is fairly well marked. The horizontal canal has two communications in its course—the usual one about its middle with the posterior canal, and the other with the posterior limb of the superior canal; the superior canal is inclined to the drooping type. The cochlea is proportionately long, and the perilymph recess is relatively rather small.



CORACIIFORMES

THE MEMBRANOUS LABYRINTH OF THE BURROWING OWL

Speotyto cunicularia

The labyrinth of the burrowing owl is rather large relatively to the size of the bird. It measures 12.5 mm. from the most distant point on the vertex of the superior canal to the tip of the cochlea.

The *cochlea* measures 5.25 mm. in length, and the diameter of the tube is 1.5 mm. at the beginning of the organ.

The diameter of the *vestibule* is 3.5 mm. in its greatest breadth ; and the longest axis of the oval window is rather less than 1.75 mm. in length.

The internal diameter of the *superior canal* is 6·0 mm. and the external 9.5 mm. The height of the vertex of the canal above the vestibule is 4.5 mm., and the diameter of the canal itself at the vertex is 1.0 mm. The internal diameter of the *posterior canal* is 4.5 mm., and the external diameter is 6.0 mm. The height of the vertex of the canal above the vestibule is 3.75 mm., and the diameter of the canal itself at the vertex is 1.0 mm. The *horizontal canal* measures 5.0 mm. in its internal, and 6.75 mm. in its external diameter. The height of the vertex of the canal above the vestibule is 3.0 mm., and the diameter of the canal itself at the vertex is 1.0 mm.

A large saddle-shaped otolith is present at the tip of the cochlea. There may be, and probably are, otoliths present in the vestibule, but if so they are too small to be visible to the naked eye.

In its general appearance the labyrinth of the burrowing owl is a beautiful object, the curves of the organ being regular in outline. The superior canal is of the drooping type. The horizontal canal bulges outwards in that portion which lies in front of the posterior canal. There is a communication between the horizontal and posterior canals at the point at which they cross.

As stated above, the superior canal is of the drooping type ; nevertheless its posterior limb comes so low down that it is in contact with the posterior limb of the horizontal canal at one point, and a communication between the two occurs. In this respect, therefore, the labyrinth is similar to those of the buzzard and pigeon, but in these two birds the superior canal is of the upright type. Thus the owl is unique in respect to the fact that, although this canal is of the drooping type, the communication referred to is present. It is interesting to note that, in his drawing and description of the labyrinth of the eagle owl (*Bubo innavus*), Retzius does not figure this communication between the superior and horizontal canals. It is, therefore, either absent in that particular genus, or the description given by Retzius is incorrect. The latter alternative is highly improbable in the case of such an accurate observer. The ampullæ are fairly large in proportion to the size of the labyrinth and the cristæ acusticæ are complex, there being three crests in that portion of the neuro-epithelium which occupies the floor of the ampulla.

The cochlea possesses a curve which is more marked than in the majority of the birds, and the organ is, on the whole, long and thin relatively to the size of the labyrinth. In this respect it agrees with those of the cockatoo and thrush. While the cochlea as a whole is long, the portion assigned to the lagena is small, and the helicotrema is relatively near the tip of the organ, the portion occupied by the basilar membrane being correspondingly long. The perilymph recess is rather small, and somewhat flattened from behind forwards. The tip of the cochlea is not bulbous.

LITERATURE.—Breschet, *Récherches anatom. et physiolog. sur l'organe de l'audition chez les oiseaux*, Paris, 1836. Huschke, *Loc. cit.* Deiters, *Loc. cit.* Retzius, *Op. cit.*

PLATE XXXIV

THE RIGHT MEMBRANOUS LABYRINTH OF THE CARRION CROW

Corvus corone

× $4\frac{3}{4}$

The organ is suspended by the superior canal and is viewed from the outer aspect. The letters indicate the structures.

S.	Superior canal.
P.	Posterior canal.
A. P.	Ampulla of posterior canal.
O.	Otolith.
A. H.	Ampulla of horizontal canal.
S. V.	Beginning of scala vestibuli.
F. O.	Fenestra ovalis.
A. C.	Aqueduct of cochlea.
P. R.	Perilymph recess.
F. R.	Fenestra rotunda.
L.	Lagena.

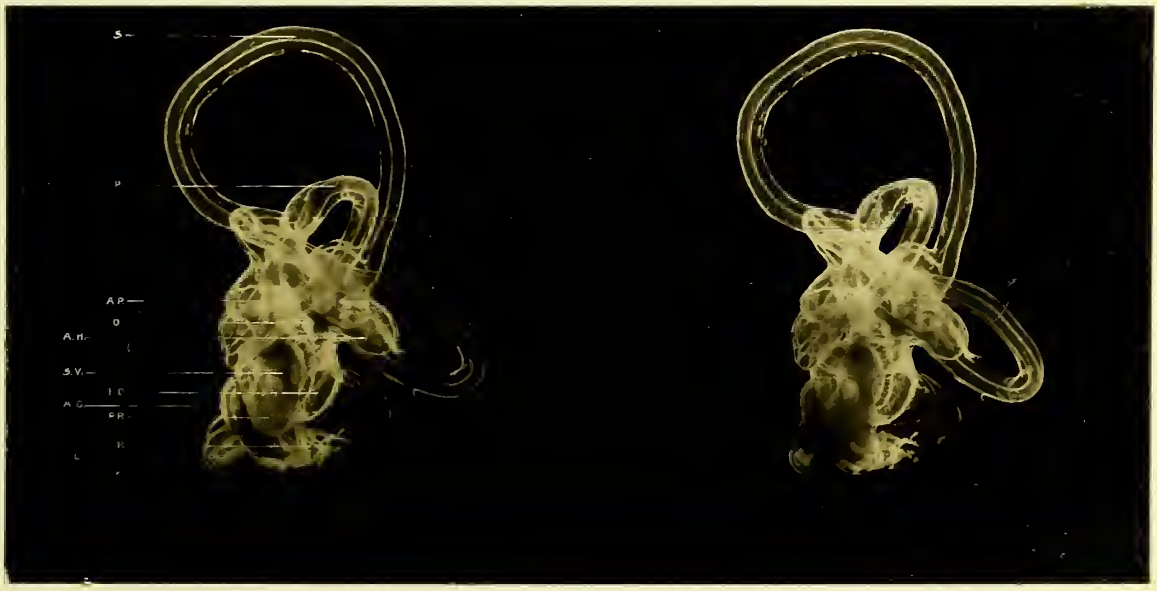

S
P
A.P.
O
A.H.
S.V.
I.C.
A.C.
P.R.
R
L

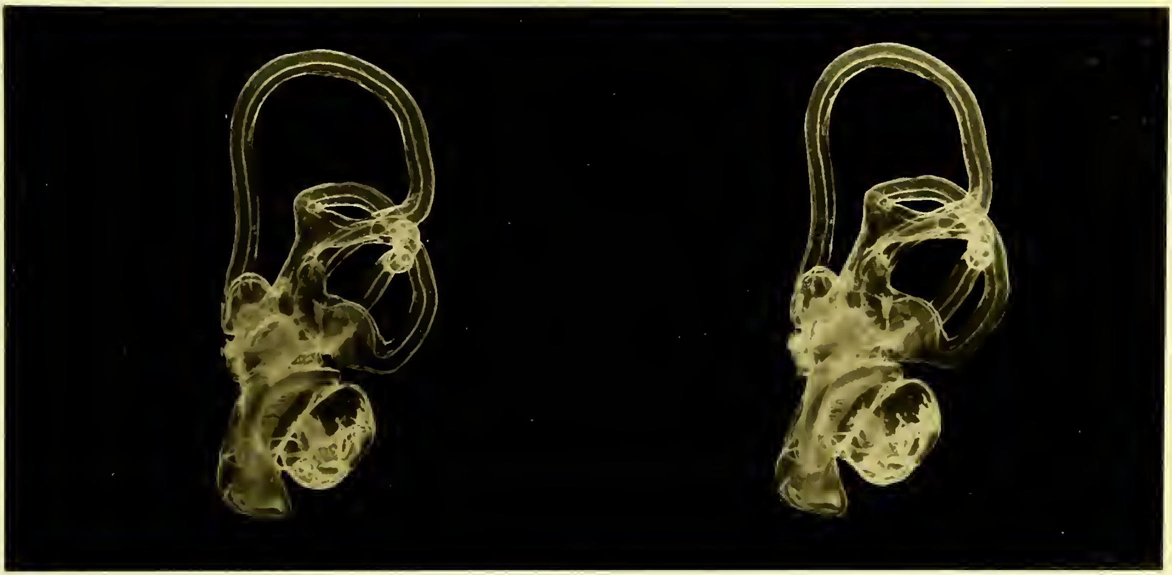
PLATE XXXV

THE RIGHT MEMBRANOUS LABYRINTH OF THE CARRION CROW

Corvus corone

× 5

The organ is viewed from the inner aspect, behind and slightly below. The cristæ acusticæ of the ampullæ are complex. The cochlea is rather short, but this is due in large part to the very short lagena. The position of the helicotrema is indicated by the vein which passes through it to the posterior portion of the cochlea and then on to the perilymph recess. The latter cavity is roughly oval in shape when seen in this position, and from its posterior upper surface the aqueduct of the cochlea may be seen as a fairly wide tube curving upwards and forwards. There is no indication of any nerve twig passing from the posterior ampullary nerve to the perilymph recess. The macula neglecta, with the small nerve supplying it, is seen immediately in front of the posterior ampulla.



PASSERIFORMES

THE MEMBRANOUS LABYRINTH OF THE CARRION CROW

Corvus corone

Considered as a whole the labyrinth of the carrion crow presents a high degree of development. This is particularly noticeable in the cochlea in which the lagena is relatively small.

The labyrinth measures 13.0 mm. in extreme length from the vertex of the superior canal to the tip of the cochlea. The *cochlea* has a length of 3.5 mm. from the front of the oval window to the tip, and the diameter of the tube at its beginning is 1.5 mm.

The longest diameter of the *vestibule* is 3.5 mm. and the major axis of the oval window is 1.75 mm. in length. A long flat otolith is found in the utricle, with its anterior extremity projecting into the ampulla of the horizontal canal. The otolith is constricted at the junction of its outer and middle thirds.

The *superior canal* measures 5.75 mm. in internal, and 7.0 mm. in external diameter. The height of the vertex of the canal above the vestibule is 6.5 mm., and the diameter of the canal itself at the vertex is 1.0 mm. The *posterior canal* has internal and external diameters of 4.75 mm. and

6.5 mm. respectively. The height of the vertex of the canal above the vestibule is 3.0 mm., and the diameter of the canal itself at the vertex is 1.0 mm. The *horizontal canal* measures 6.5 mm. in internal, and 8.0 mm. in external diameter. The height of the vertex of the canal above the vestibule is 4.5 mm., and the diameter of the canal itself at the vertex is 1.0 mm.

In all three canals the perilymph space is well marked. The superior canal is of the upright type and its posterior limb descends low, so that it comes in contact with the posterior limb of the horizontal canal; and at this point there is a communication between the two. One of the most curious features of this labyrinth is the large size of the horizontal canal. It is actually larger than the superior canal, this being the only avian labyrinth in which such a relationship exists. The posterior is the smallest of the canals. The horizontal canal is slightly undulating in outline, and the portion in front of the point of communication with the posterior canal is relatively large.

The cristæ acusticæ in the ampullæ are complex, but the ampullæ, though fairly large, are proportionately smaller than in the buzzard.

The perilymph recess is of moderate size, and is oval when viewed from above and within. The aqueduct of the cochlea opens out of the inner posterior extremity of the cavity, and, curving upwards, forwards and outwards, has its outlet behind and above the middle of the posterior surface of the cochlea. The perilymph recess does not receive a twig from the nerve to the posterior ampulla such as is usually found in the labyrinth of birds. The round window occupies the lower portion of the external wall of the perilymph recess, and is almost immediately below the oval window. It is much smaller than the latter. The tip of the cochlea is bulbous when seen from within, and a minute otolith is found in the anterior portion of the lagena. As stated above, the lagena is small in comparison with the rest of the cochlea, and the helicotrema is nearer the tip of the organ than is usually the case.

Pigment is not found in the labyrinth in quantity sufficient to be recognised by the naked eye.

LITERATURE.—Deiters, *Loc. cit.* Hasse, *Op. cit.*

PLATE XXXVI

THE RIGHT MEMBRANOUS LABYRINTH OF THE SONG-THRUSH

Turdus musicus

× 6

The organ is viewed from above and slightly behind. The superior canal is broken just before its junction with the horizontal. In addition to the usual communication between the horizontal and posterior canals there is a communication between the posterior limbs of the superior and horizontal canals. The ampullæ are large and almost hemispherical in shape. The recessus utriculi is large and contains a flat otolith. For description of cochlea see Plate XXXVII.

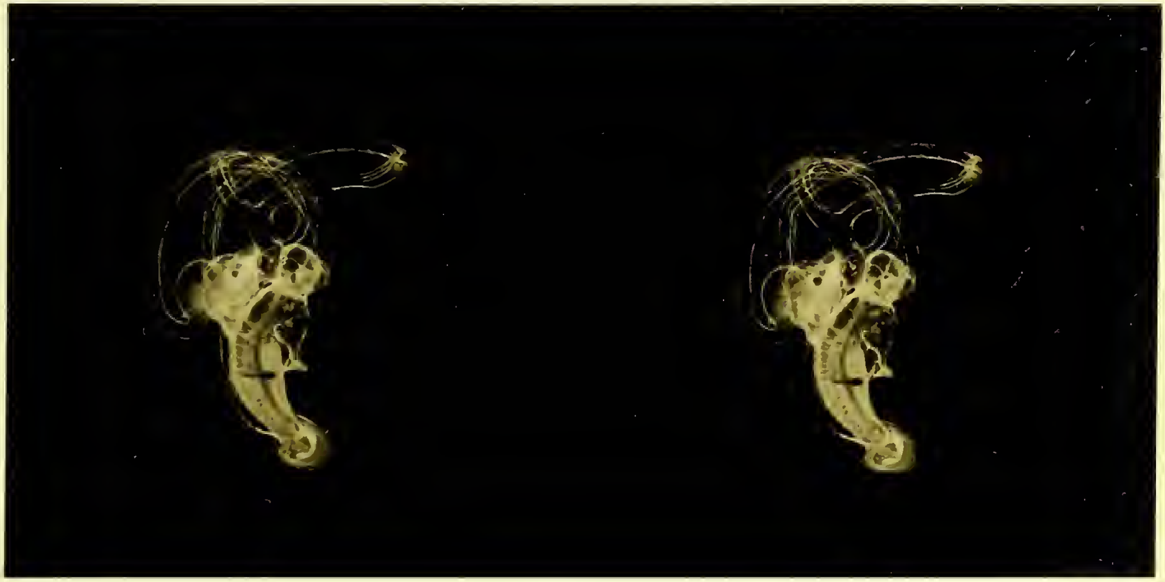


PLATE XXXVII

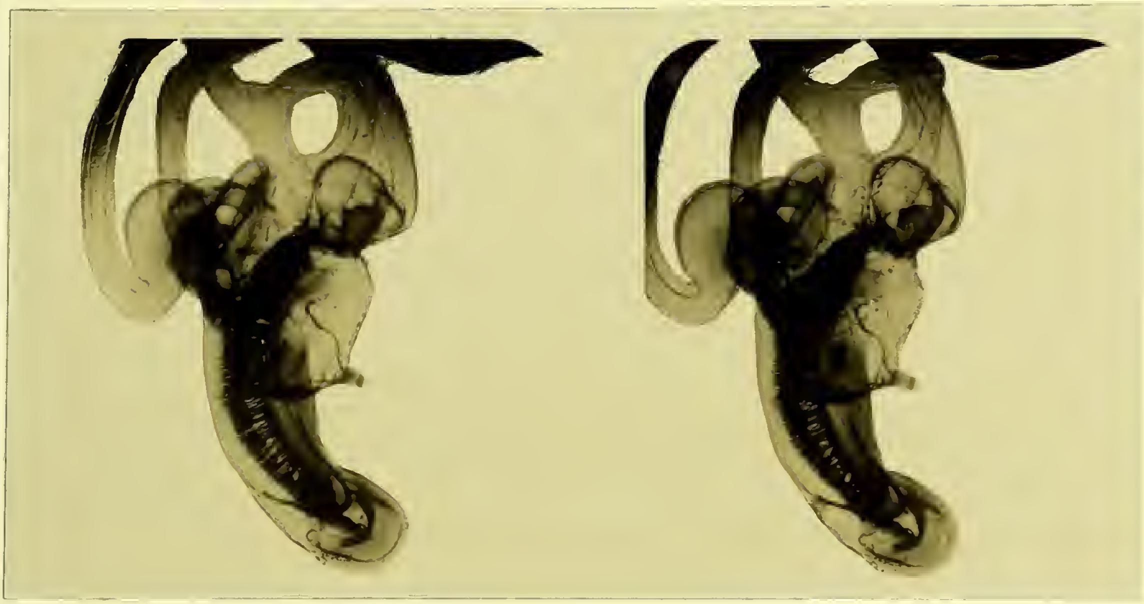
PORTION OF THE RIGHT MEMBRANOUS LABYRINTH OF THE SONG-THRUSH

Turdus musicus

× 11 ca.

The organ is viewed from below. The very highly developed tegmentum vasculosum is seen along the whole course of the basilar portion of the cochlea, but does not pass into the lagena, the veins of this portion being in the form of a clump of intertwining vessels. In the lagena may be seen the well-marked crescent-shaped otolith. A large vein is seen passing through the helicotrema and bending sharply backwards towards the perilymph recess. The latter cavity is seen to be roughly oval, and the short aqueduct of the cochlea is seen at its inner posterior extremity.

In the upper portion of the photograph the recessus utriculi is well shown with its flat translucent otolith. The cristæ in the ampullæ are complex.



PASSERIFORMES

THE MEMBRANOUS LABYRINTH OF THE SONG-THRUSH

Turdus musicus

Although the thrush belongs to the same order as the crow there are some noticeable differences in the appearances found in the labyrinth. These will be referred to after the measurements have been given.

The whole labyrinth measures rather more than 8.5 mm. in its greatest length from the vertex of the superior canal to the tip of the cochlea. The length of the *cochlea* from the tip to a point immediately opposite the oval window is rather less than 3.5 mm., and the diameter of the cochlea at this point is 1.0 mm.

The *vestibule* measures 2.25 mm. in its longest diameter, and the major axis of the oval window has a length of rather less than 1.0 mm.

The *superior canal* has internal and external diameters of 4.0 mm. and 5.0 mm. respectively. The height of the vertex of the canal above the vestibule is 4.0 mm., and the diameter of the canal itself at the vertex is 0.5 mm. The *posterior canal* measures 3.0 mm. in internal, and 4.25 mm. in external diameter. The height of the vertex of the canal above the vestibule is 2.75 mm., and the diameter of the canal itself at the vertex is 0.5 mm. The *horizontal canal* has internal and external diameters of 4.0 mm. and rather more than 4.75 mm. respectively. The height of the vertex of the canal above the vestibule is fully 2.5 mm., and the diameter of the canal at the vertex is 0.5 mm.

The superior canal is distinctly of the upright type, and the posterior limb of the canal descends low in such a way that there is a communication between this canal and the horizontal, a condition not usual in birds, but found in the buzzard, the crow, the owl and some others. The usual communication between the posterior and horizontal canals is, of course, present. The perilymph space is present in all the canals and is well marked. As regards size the superior is the largest and the posterior the smallest, a relationship which is the usual one in birds, but not that which is found in the crow, in which the horizontal is the largest of the canals. The ampullæ are rather large and the cristæ acusticæ are complex, having three crests in that portion which lies on the floor of the ampulla. The fanlike structures on the lateral walls of the ampullæ are also present.

In the utricle the most interesting feature is a peculiar conical projection immediately behind the ampullæ of the superior and horizontal canals. This structure is described by Retzius and termed the recessus utriculi ; being a diverticulum from the utricle. There is a neuro-epithelium on its floor, which is supplied by a twig from the nerve to the superior and horizontal ampullæ. In the thrush the recessus utriculi is more prominent than in any other bird which the writer has examined.

The cochlea of the thrush is well curved and relatively large; indeed, with those of the owl and the cockatoo, it is proportionately the largest found among the birds examined. As is the case also in these birds the large size of the organ is owing entirely to the increased length of the basilar portion, the lagena not being proportionately any larger than in other birds. Further, the tegmentum vasculosum is very large, and the branching venous spaces, about fifty-eight in number, are more numerous than in any bird which has been examined. This indicates a particularly rich supply of blood to the basilar portion of the cochlea, and therefore great functional activity in that structure. It is interesting to note that the tegmentum vasculosum terminates at the inner extremity of the basilar portion of the cochlea, the veins of the lagena consisting of a mass of intertwining venules. This is different from the arrangement of the blood-vessels as found in the duck, in which the tegmentum vasculosum extends almost to the tip of the lagena.

The perilymph recess is found in the usual place on the posterior and lower surface of the base of the cochlea. It is curious that Retzius does not refer to it in the thrush, for it is relatively as large as in other birds, and is also of interest for another reason. This is, that the aqueduct of the cochlea opens directly out of its upper, inner and posterior extremity, in a way similar to that found in the ostrich, the hen, and the tinamou. It is quite unlike that found in most birds, in which the channel begins at the lower and inner extremity of the perilymph recess and curves upwards in contact with it before opening into the cranial cavity.

The helicotrema is situated far inwards in the cochlea of the thrush, this, of course, being due to the relatively large part of the organ which is occupied by the basilar portion. The nerve to the latter portion is relatively large. Thus the cochlea of the thrush shows certain anatomical differences from those of other birds, such as we might almost expect on considering the functional importance of the organ in a singing bird.

The writer has not been able to find otoliths of a size large enough to be seen by the naked eye in the vestibule of the thrush, but in the lagena there is one of considerable size, and crescentic in shape.

The differences between the labyrinth of the thrush and that of the crow are, the relatively greater size of the cochlea and of the recessus utriculi in the thrush, and the difference in the course of the aqueduct of the cochlea in the two birds.

LITERATURE.—Retzius, *Op. cit.* Huschke, *Loc. cit.* Deiters, *Loc. cit.* Hasse, *Loc. cit.*

Before leaving the description of the labyrinth of birds, it may not be out of place to make a few remarks on the more noticeable similarities and differences found in the organ in the various orders. These remarks, it must be understood, are meant merely as suggestions for those who are interested in the difficult subject of the classification of birds, and the writer has no intention of entering into speculative matters concerning the affinities of different orders of birds, or their relative degrees of antiquity.

Very marked similarity is found to exist between the labyrinths of the passeriformes, charadriiformes and, to a slightly less extent, the falconiformes. In all three the superior canal is of the upright type and there is a communication between the posterior limbs of that canal and the horizontal canal. In all three orders, moreover, the lagena is comparatively small, and the neuro-epithelium on the floor of the ampullæ is complex. The aqueduct of the cochlea is similar in all except, curiously, in the case of the thrush among the passeriformes. In the falconiformes the superior canal is a little different from that found in the other two orders mentioned.

The order gruiformes has also the upright type of superior canal; but in this case there is no communication between the posterior limb of that and the horizontal canal.

In all the remaining orders the superior canal is of the drooping type, though the canal itself varies in shape and in the extent to which it droops backward. In these orders, moreover, the lagena occupies a relatively larger, and the basilar portion a relatively smaller, part of the cochlea than in the passeriformes, charadriiformes and falconiformes; and, on the whole, the tegmentum vasculosum reaches a greater degree of development in the last three orders than in the others.

Between the galliformes and the tinamiformes there is this point of agreement, the aqueduct of the cochlea opens out of the inner and upper extremity of the perilymph recess, and the same is true of the ostrich. This feature, however, is also found in the thrush, so that it may not be of much value in deciding affinities.

The cuculiformes (slender-billed cockatoo) and the coraciiformes (burrowing owl) differ from other orders which have the drooping type of superior canal. In the latter of these two orders there is a communication between the posterior limbs of the horizontal and superior canals.

The labyrinths of the ratitæ differ considerably from those of all other birds, and even among themselves there is not much similarity. It must be remembered, however, that the term ratitæ has a much wider significance than the names of the various orders in the carinate birds, so that it is not surprising to find considerable differences in the labyrinths of the ostrich, the rhea and the apteryx.

As regards the cochlea, in all three the organ is short and relatively thick, these features being undoubtedly most pronounced in the ostrich. Indeed, the cochlea of the ostrich is obviously more primitive in type than that of either the rhea or apteryx, though in other respects the labyrinth of the last mentioned may be more primitive—for example, in regard to the very large otolith, and the wide opening of the aqueduct of the vestibule. If the presence of a communication between the posterior and horizontal canals be evidence of more recent lineage, then in this respect the rhea is the least ancient of the three.

In short, it may be suggested that the labyrinths of the ostrich and apteryx are more primitive in type than that of the rhea. But this, of course, does not mean that the relationship between the two former is necessarily closer ; indeed, it is probable that the reverse is the case.

REPTILES AND AMPHIBIANS

REPTILES AND AMPHIBIA

It is the intention of the writer, as stated in the introduction in the first volume, to describe only very briefly the labyrinths of the reptiles and amphibia. This is a matter not of choice only, but also of necessity. There is considerable difficulty in obtaining specimens belonging to these divisions of the animal kingdom of a size sufficient to be examined satisfactorily by the writer's method. Again, some of the animals belonging to these orders have a capsule of cartilage surrounding the labyrinth, and since the embedding media penetrates this cartilage, the preparation of the object is difficult and sometimes impossible.

Careful and detailed examinations have been made of the labyrinths of reptiles and amphibia by previous anatomists, among whom may be mentioned Breschet, Deiters, Hasse, Meyer, Retzius, Coggi and others. But the organ varies so much in different orders of these divisions that the subject cannot be said to be by any means exhausted, and there is ample field for further work in establishing the differences which are to be found in various species. With respect to the cochlea, that large gap which exists between the comparatively rudimentary organ in the tortoise, snake and lizard, and the well-developed tube which it forms in the alligator should, if possible, be filled up. The writer has, to a certain extent, been able to do this by the discovery of a cochlea of intermediate dimensions in the teguixin.

GENERAL REMARKS ON THE LABYRINTH OF THE REPTILES

It is obvious at first sight that the labyrinth of the reptile is in general very different from that of the bird, on the one hand, and that of the mammal on the other. Among the reptiles examined by the writer not a single one can be said, as far as the labyrinth is concerned, to show any similarity to either of the divisions named, beyond the fact that they all possess three semicircular canals. Among the reptiles examined by other writers, only in the case of the alligator can the labyrinth be said to present any outward similarity to that of the birds. Taking a typical reptilian labyrinth, such as that of the tortoise or the lizard, it will be seen that the canals are angular, the vestibule is very large, the otolith apparatus is extremely well developed, and the cochlea is particularly small. Thus the organ differs in every one of its three divisions from that of mammals and birds. It is true, of course, that in some matters of microscopic detail there is a certain amount of resemblance, but with that we are not concerned here. The fact remains that the typical reptilian labyrinth of present times is by no means so similar to that of the bird as many anatomists seem to think; for the labyrinth of the alligator is very different from a typical reptilian one.

The organ may, in its typical form, be fairly accurately described as pyramidal in shape, the cochlea forming the apex of the pyramid. The cochlea itself is usually in the form of a cone, but in rare instances it is drawn out in the form of a tube as, for example, in the teguixin and the alligator. It is attached to the inner wall of the vestibule, and there is a noticeable constriction between it and the latter cavity. The aqueduct of the cochlea is depicted by Retzius as a wide tube, which, arising from the lower surface of the organ, curves round its posterior border and opens into the cranial cavity behind and above the cochlea. Its course, therefore, is not unlike that of the bird, but in the latter there is a well-marked perilymph recess from which the aqueduct opens, while in the reptile this space is not always present as a distinct cavity. The aqueduct of the cochlea is not seen in any of the photographs shown in these pages, except in that of the teguixin.

The structures contained within the cochlea are so small in most reptiles that investigation by means of the microscope is necessary for the study of the minute details, and no description of the organ will be given beyond its general macroscopic appearance.

The vestibule in the reptiles is usually the bulkiest portion of the labyrinth. It varies in shape from that of an irregular sphere to an equally irregular oval cavity. The otolith apparatus is large, and consists, not of a single crystal, or of a few crystals, as in many fishes, but of a collection of innumerable minute crystals which are held together by a semi-gelatinous capsule. In many reptiles the otolith apparatus occupies the greater part of the vestibule, and in all it is relatively large. In the photograph of the giant tortoise it will be noticed that no otoliths are visible, but in this case their absence is due to the fact that the acid used in preparation has obtained access to and dissolved them.

The canals are distinguished from those of the birds, mammals and amphibians by their angularity and the comparative straightness of their outline. In this respect, however, exception must be made in the case of the horizontal canal, which has a curved outline as in the other divisions of the animal kingdom. It is interesting to note that, in the case of mammals in which angularities in the canals occur, such as the platypus and the sloth, the horizontal canal remains curved. The ampullæ of the canals do not appear, in general, to be so complex as those of the bird. The perilymph space is well marked in all the canals, and in no case hitherto examined has it been found obliterated at any part of the circumference. This condition is in keeping with that found in birds, but the reverse of the condition found usually among the mammalia. The canals themselves are not set in planes at right angles to one another, but are frequently in planes which cut one another at angles of forty-five degrees. This fact is of importance when it is remembered that some physiologists have assumed that the planes of the canals are always at right angles to each other, and on that ground, have supported various theories as to the function of these organs. Such theories may or may not be correct, but it is a mistake to attempt to support them by statements which are found to be erroneous when examined in the light of fact.

Pigment is usually present in the labyrinth of the reptiles, and in some cases, such as the gecko, it is extremely abundant. In the chelonia, however, it is not found, at least, in the two examples which have been examined—the giant tortoise and the salt-water terrapin.

Before passing on to consider the labyrinths of individual reptiles, a small but interesting point in the comparative anatomy of the subject may be noted. It has been shown that in the vast majority of birds, and in very rare cases in the mammalia, there is a channel of communication between the posterior and horizontal canals in their course. In the reptiles this channel is usually present ; indeed, it is absent only in one labyrinth out of the six which have been examined, that exception being the gecko. The significance of this matter, both from the evolutionary and physiological points of view, is very obscure, and more data will be required before any satisfactory speculation can be made in regard to it. At present the facts may be stated briefly, as follows. The channel of communication is found in all birds that have been examined except the ostrich and the apteryx, both of which are ancient types. On the other hand, the channel is absent from all mammalian labyrinths except those of the common mole and a few of the polyprotodont marsupials, these also being ancient types. In the only two examples of the amphibia that have been examined the channel is present, but since neither of these—the toad or the frog—is of great antiquity, the fact may not have much significance from the phylogenetic point of view.

As in the other portions of this work, the classification adopted by the writer is that drawn up by Gadow.

PLATE XXXVIII

THE RIGHT MEMBRANOUS LABYRINTH OF THE GIANT TORTOISE

Testudo gigantea

× 5½ ca.

The organ is viewed from the inner aspect and slightly behind. It is rotated counter-clockwise to the extent of about 60°, so that the posterior canal is uppermost. The letters indicate the different structures.

P.	Posterior canal.
A. P.	Ampulla of posterior canal.
C. C.	Common crus of superior and posterior canals.
N. P.	Nerve to ampulla of posterior canal.
H.	Horizontal canal.
N. P. R.	Nerve to macula neglecta or to perilymph recess[1] (*see* text).
A. V.	Aqueduct of vestibule.[2]
S.	Superior canal.
N. H.	Nerve to horizontal canal.
M. L.	Macula lagenæ.
M. U.	Macula utriculi.
M. B.	Macula basilaris.
A. S.	Ampulla of superior canal.

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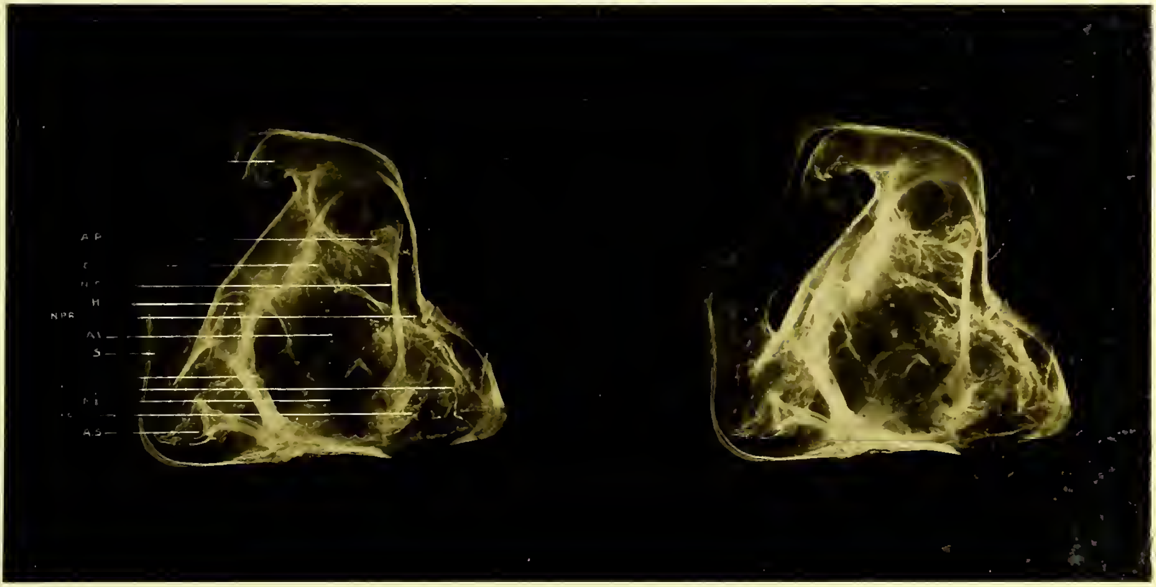
[1] The line opposite N. P. R. in the photograph should be continued one millimetre to the right.

[2] The line opposite A. V. should be continued one millimetre to the right.


A P
C
H
NPR
AI
S
MI
A.S

CHELONIA

THE MEMBRANOUS LABYRINTH OF THE GIANT TORTOISE

Testudo gigantea

The labyrinth of this reptile is not so large in proportion to the size of the animal, as might, on first consideration, be expected ; but it must be remembered that, as was remarked when describing the organ in the birds, the dimensions of the labyrinth bear a much closer relationship to the size of the head than to the size of the body.

The labyrinth measures 9.5 mm. in its greatest diameter from the uppermost point on the superior canal to the tip of the cochlea, the latter being the lowest point of the organ. The diameter of the *cochlea* at its base where it is attached to the vestibule is 4.5 mm. The length of the cochlea from base to tip is 3.75 mm.

The *vestibule* measures 6.0 mm. in its longest diameter, and the major axis of the oval window has a length of 2.75 mm. In all probability otoliths are present in the vestibule, but in the example obtained by the writer these were not found, owing no doubt to the acid used in preparation having obtained access to them. The reason for supposing that otoliths are present in the vestibule of this animal is that they are found in the terrapin, and in all other reptiles that have been examined. The aqueduct of the vestibule is a small straight tube which opens on the upper surface of the vestibule internal to the region at which the broad common crus of the superior and posterior canals opens into that cavity. The small intracranial opening is seen almost in the middle of the picture, and from that point the aqueduct runs downwards and to the right, gradually widening out into the vestibule. It is very faintly seen in the photograph, but is visible if the light be brilliant.

The *superior canal* measures 5.5 mm. in internal, and 7.5 mm. in external diameter, the common limb of the superior and posterior canals being included in the measurements. The height of the vertex of the canal above the vestibule is 1.0 mm., and the diameter of the canal itself at the vertex is 2.0 mm. The *posterior canal* has internal and external diameters of 5.0 mm. and 8.5 mm. respectively, the common limb being included in the measurements. The height of the vertex of the canal above the vestibule is 1.5 mm., and the diameter of the canal itself at the vertex is rather more than 1.5 mm. The *horizontal canal* measures 5.75 mm. in internal, and 9.0 mm. in external diameter. The height of the vertex of the canal above the vestibule is 1.0 mm., and the diameter at the vertex is rather more than 1.5 mm.

Pigment is not found in the labyrinth of the tortoise. The black streaks seen in the photograph are the result of an attempt to inject the arteries, which was made before the temporal bones were sent on for preparation.

The distribution of the nerves is very well seen in the photograph. Before entering the labyrinth the auditory nerve divides into two main portions—an outer one to supply the macula acustica of the utricle and the ampullæ of the superior and horizontal canals, and an inner one which supplies the saccule, the cochlea and the ampulla of the posterior canal. In the photograph the former of these is to the left, and the latter to the right.

Immediately on entering the labyrinth the first branch divides into three portions, one of these running to the ampulla of the superior canal, the second to the ampulla of the horizontal canal, and the third to the macula acustica of the utricle. In the photograph the first of these is seen furthest to the left, the branch to the horizontal ampulla is a little longer and is seen to the right of the first, while the third branch passes outwards to the utricle; this third branch appears to the reader to be receding, and is seen as a faint haziness in the middle of the lower portion of the picture.

The second main division of the auditory nerve also breaks up, immediately on entering the labyrinth, into three branches. One of these is long and thin and runs to the ampulla of the posterior canal. It is very clearly seen in the photograph in the vertical position, but in its natural position it is almost in the horizontal plane. (In the photograph the labyrinth is rotated counter-clockwise to a considerable extent.) From the branch to the posterior ampulla there arises a small twig which passes over the posterior wall of the cochlea where the latter widens out into the vestibule. This twig is visible in the photograph a little to the right of the nerve to the posterior ampulla, but its actual junction with this nerve is not seen, as it has been broken in the process of preparation. This little twig from the nerve to the posterior ampulla is of considerable interest, for it undoubtedly corresponds to that which has been described by the writer in the part referring to the labyrinth of the bird; but in the bird the twig passes to the perilymph recess (*vide* p. 105, vol. ii.). The question as to whether this is to be regarded as the nerve referred to by Retzius, under the name of the branch to the macula neglecta, has already been discussed when describing it in the labyrinth of the bird. The same difficulty occurs in the case of the reptile, for the twig does not run the course which Retzius ascribes to the branch to the macula neglecta. At the same time, the present writer has not been able to find any branch which corresponds to the latter, and it may be, therefore, that the nerves described are identical, and that an error has arisen as to the course which it runs.

Another branch of the second division runs a very short course to supply the cochlea. This branch leaves the main division along with the nerve to the posterior ampulla, but immediately branches off from the latter, almost at right angles, and at once breaks up into numerous small bundles which terminate in the oval lagena. This branch is seen in the photograph running horizontally, but in the natural position it is almost vertical.

The last branch of the second main division also breaks up immediately into numerous small bundles, and runs outwards to terminate in the macula basilaris. It is not very distinctly seen in the photograph because it runs in a plane almost directly corresponding to the line of vision; but if looked for carefully it will be seen a millimetre or so downwards and to the left from the lagena. The macula basilaris corresponds to the whole of the cochlea of mammals, and to the basilar portion of that organ in birds.

LITERATURE.—Hasse, *Anat. Studien*, Hft. ii. No. 7, 1871. Kuhn, *Arch. f. Mikroscop. Anat.* Bd. xx. S. 271, 1881. Retzius, *Op. cit.* vol. ii. S. 18.

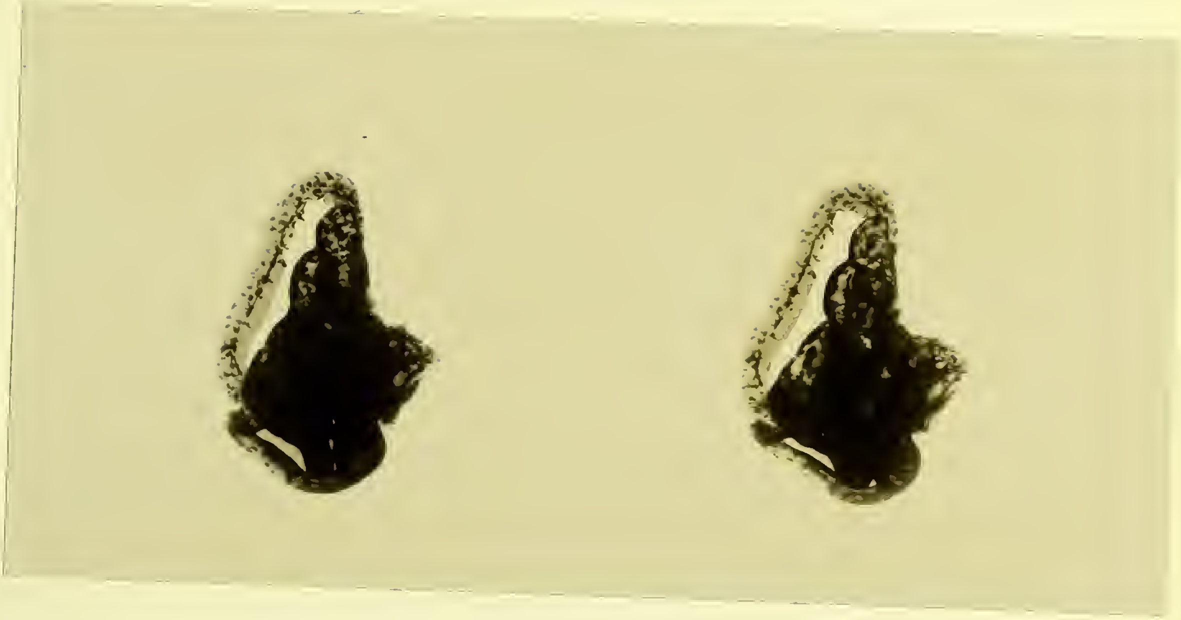
PLATE XXXIX

THE LEFT MEMBRANOUS LABYRINTH OF THE MOORISH GECKO

Tarentola mauretanica

× 8½

The organ is rotated counter-clockwise to the extent of 90°, so that the ampulla of the superior canal is almost at the top, and that of the horizontal canal immediately below and to the left of it. The deposit of pigment is so great that very little of the structures can be seen. The cochlea is seen as a cone-shaped structure to the right, and the ampulla of the posterior canal is immediately below it. It will be seen, at the lowest part of the photograph, that the posterior limb of the horizontal canal passes under the posterior canal without any channel of communication. The labyrinth differs from those of other reptiles in this respect.



LACERTILIA

GECKONIDÆ

THE MEMBRANOUS LABYRINTH OF THE MOORISH GECKO

Tarentola mauretanica

The most noticeable feature of the labyrinth of the gecko is the great abundance of pigment which is scattered throughout the whole organ, preventing a satisfactory view of the other structures.

The labyrinth is small, measuring only 3.0 mm. in length from the uppermost point on the superior canal to the tip of the cochlea. The diameter of the *cochlea* at its junction with the vestibule is 1.25 mm. in length, and the length of the organ from the same point to the tip is rather less than 1.5 mm., thus the organ may be said to form a broad based cone.

The *vestibule* is roughly cone-shaped, with the apex of the cone reaching almost to the junction of the superior and posterior canals. It measures 2.5 mm. in its greatest diameter, but owing to the thick deposit of pigment it is impossible to say whether the cavity contains any otoliths, or indeed, to give any details of the structures within.

The *superior canal* measures rather less than 2.75 mm.

in internal, and rather more than 3.0 mm. in external diameter. The height of the vertex above the vestibule is 0.5 mm., and the diameter of the canal itself is rather less than 0.5 mm. The *posterior canal* measures 1.0 mm. in internal, and 2.0 mm. in external diameter. The height of the vertex above the vestibule is 0.25 mm., and the diameter of the canal is rather less than 0.5 mm. The *horizontal canal* measures 2.0 mm. in internal, and rather more than 2.75 mm. in external diameter. The height of the vertex above the vestibule is less than 0.25 mm., and the diameter of the canal is 0.5 mm.

As is almost always the case in reptiles the canals are angular, the superior being the most pronounced in this respect while the horizontal is the least so. As is the case in all reptiles, the perilymph space is well marked in the canals. The planes in which the canals lie do not cut one another at right angles, but at angles of approximately forty-five degrees.

One curious feature about the labyrinth of some species of gecko is the communication which exists between that organ and the outside of the skull. Wiedersheim discovered this condition in Phyllodactylus europæus, but Leydig had described the same structure four years previously in the embryo of Lacerta agilis. The former of these writers assumed that the channel was to be looked upon as the ductus endolymphaticus, while Leydig considered it to represent the channel which runs from the labyrinth to the outer surface of the skin in the selachian fishes. Both of these writers may be correct, for it is not yet definitely decided whether the channel found in these fishes represents the ductus endolymphaticus or not. In more recent times the subject has been discussed by Poli, Netto, Keibel, Alexander, Krause and others.

In the species of gecko examined by the present writer this structure was not found, but it may have been broken in the course of preparation.

Literature.—Leydig, *Die in Deutschland lebenden Arten der Saurier*, Tübingen, 1872. Wiedersheim, *Der Aquæductus Vestibuli von Phyllodactylus europæus*, Morph. Jahrbuch, Bd. i. 1876. Poli, *Arch. f. mikroscop. Anat.* Bd. xlviii. 1897. Peter, *Arch. f. Ohrenh.* Bd. li. S. 126. Krause, *Anat. Anzeiger*, Bd. xix. Nos. 3 and 4.

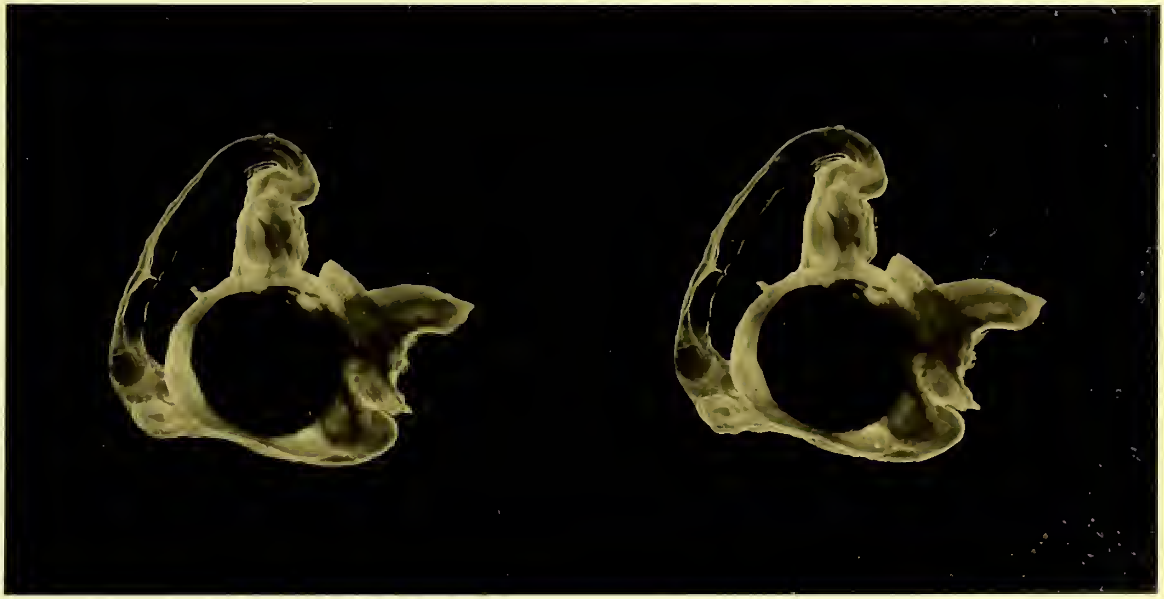
PLATE XL

THE LEFT MEMBRANOUS LABYRINTH OF THE BLACK-POINTED TEGUIXIN

Tupinambis nigropunctatus

× 5½

The organ is viewed from the inner aspect and is rotated counterclockwise to the extent of 90°, so that the ampulla of the superior canal is at the top, and that of the horizontal canal immediately below it. The ampulla of the posterior canal is at the lower right-hand corner. The large disc-shaped otolith mass is seen occupying the greater portion of the vestibule. From the upper surface of the vestibule a short, fine tube is seen which originally formed a bridge over to the superior canal at the point indicated by a small conical projection on the latter. This tubular bridge was broken in the course of preparation, but the corresponding structure may be seen in Plate XLII. The cochlea is seen as a wide tube (to the left in the photograph), with the lagena at the distal end. There is a small beak-like process at the tip of the cochlea similar to that found in the ostrich. The collar which partially encircles the neck of the cochlea contains the perilymph recess and the aqueduct of the cochlea, and it should be noted that scattered pigment granules are found here and over the adjacent portion of the cochlea; that is, in the same position as in the ostrich.



LACERTILIA

TEJIDÆ

THE MEMBRANOUS LABYRINTH OF THE BLACK-POINTED TEGUIXIN

Tupinambis nigropunctatus

The chief feature of the labyrinth of this American lizard is the comparatively great development of the cochlea. In this respect the organ shows a distant approach to that of the crocodile.

The organ measures 9.0 mm. from the uppermost point on the superior canal to the tip of the cochlea. The *cochlea* measures 1.5 mm. in diameter and 4.0 mm. in length, and there is a sharp point at the tip not unlike that which is found in the ostrich. The lagena is faintly seen near the tip of the cochlea. A few scattered granules of pigment are seen near the base of the cochlea, but the specimen from which the photograph was taken was too opaque to enable any further details within the organ to be identified. There is a collar encircling a portion of the neck of the cochlea, and in this lies the comparatively wide aqueduct of the cochlea with its opening above and to the right of the ampulla of the posterior canal. There are some scattered granules of pigment in this portion also of the organ.

The *vestibule* is a large cavity almost spherical in shape. The otolith apparatus is large and disc-shaped, and lies in nearly the same plane as the superior canal. It consists of numerous minute crystals held together by a delicate semi-gelatinous envelope. The oval window measures 1.5 mm. in its major axis. The aqueduct of the vestibule is probably present, but it cannot be identified in the photograph.

The *superior canal* measures 5.5 mm. in internal, and 7.5 mm. in external diameter. The height of the vertex above the vestibule is 1.5 mm., and the diameter of the canal is 0.75 mm. The *posterior canal* has internal and external diameters of 4.0 mm. and 5.75 mm. respectively. It is in contact with the vestibule throughout its whole course, and its diameter is 0.75 mm. The *horizontal canal* measures 4.25 mm. in internal, and 6.5 mm. in external diameter. It also is in contact with the vestibule throughout its whole course, and measures 0.75 mm. in diameter.

The perilymph space is well marked in all the canals, and these, except the horizontal, are angular. No pigment is found either in the canals or the vestibule.

In the labyrinth of the teguixin there remains to be mentioned a curious little structure which has not before been described in any animal. It consists of a fine tube passing as a bridge from the upper surface of the vestibule to the middle of the superior canal. So far as can be ascertained this tube unites the endolymph spaces of these two structures. In the specimen from which the photograph was taken the tube was broken, but the ends of it are clearly visible. It is interesting to note that this structure is also found in the labyrinth of the python (Plate XLII.), but not in that of the lizard.

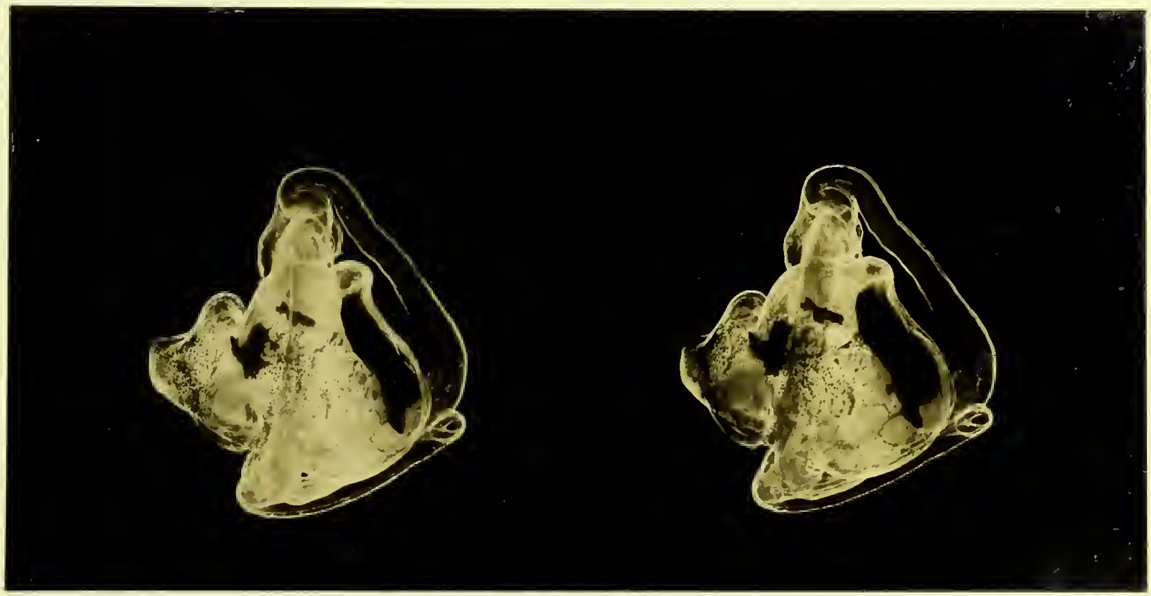
PLATE XLI

THE LEFT MEMBRANOUS LABYRINTH OF THE STUMP-TAILED LIZARD

Trachysaurus rugosus

×6 ca.

The organ is viewed from the outer aspect and is rotated clockwise to the extent of 90°, so that the ampulla of the superior canal is at the top and that of the horizontal canal immediately below it. The large vestibule contains three collections of otoliths indicated by the black patches. Pigment is scattered generally over the blunt cone-shaped cochlea and adjacent portion of the vestibule, and also over the superior canal near its junction with the posterior, at the left side of the photograph. The oval window is seen at the junction of the cochlea with the vestibule.



LACERTILIA

SCINCIDÆ

THE MEMBRANOUS LABYRINTH OF THE STUMP-TAILED LIZARD

Trachysaurus rugosus

The labyrinth of this Australian lizard does not show such a high degree of development, so far as the cochlea is concerned, as does the teguixin.

The labyrinth measures 7.5 mm. from the uppermost point on the superior canal to the tip of the cochlea. The *cochlea*, which is in the shape of a blunt cone, has a diameter of 3.5 mm. at its base, and there are some scattered granules of pigment over the surface of the organ. There is a sharp cleft which separates the cochlea from the vestibule along the anterior margin of the former, but the preparation is not sufficiently transparent to permit of the contents of the cochlea being seen.

The *vestibule* is a large cavity measuring 5.25 mm. in diameter, and is roughly spherical in shape, but with a few bulgings. The otolith apparatus is much more irregular in its arrangement than in the teguixin or python, and consists of one main portion lying along the upper wall of the vestibule and several smaller collections which are scattered over the lower and inner walls. The oval window measures rather less than 2.0 mm. in its major axis. A few scattered granules of pigment are seen over the outer wall of the vestibule.

The *superior canal* measures 5.5 mm. in internal, and 7.5 mm. in external diameter. The height of the canal above the vestibule is rather more than 0.5 mm., and the diameter is 1.0 mm. The *posterior canal* has internal and external diameters of 4.0 mm. and 6.5 mm. respectively. The canal is in contact with the vestibule throughout, except at the point at which the horizontal canal intervenes, and the diameter is nearly 1.0 mm. The *horizontal canal* measures 5.0 mm. in internal, and 7.0 mm. in external diameter. Its diameter is 0.75 mm., and it lies in contact with the vestibule throughout its whole course. The planes of the canals cut one another at angles of about forty-five degrees, and the perilymph space is well marked in all. A few scattered granules of pigment are found in the wall of the superior canal just before its junction with the posterior to form the common limb.

The superior and posterior canals are angular at their turning-points and slightly undulating in outline, but the horizontal canal is curved. There is a channel of communication between the posterior and horizontal canals at the point at which they cross.

Though in all probability the aqueducts of the vestibule and of the cochlea are both present in the labyrinth of this reptile, they are not visible in the photograph, having apparently been broken off in the process of preparation.

LITERATURE.—Hasse, *Anat. Studien*, Hft. iv. No. 19, 1873. Paul Meyer, *Etudes histolog. sur le labyrinthe membraneux, etc.* Strasbourg, 1876. Retzius, *Op. cit.* vol. ii. S. 86, etc.

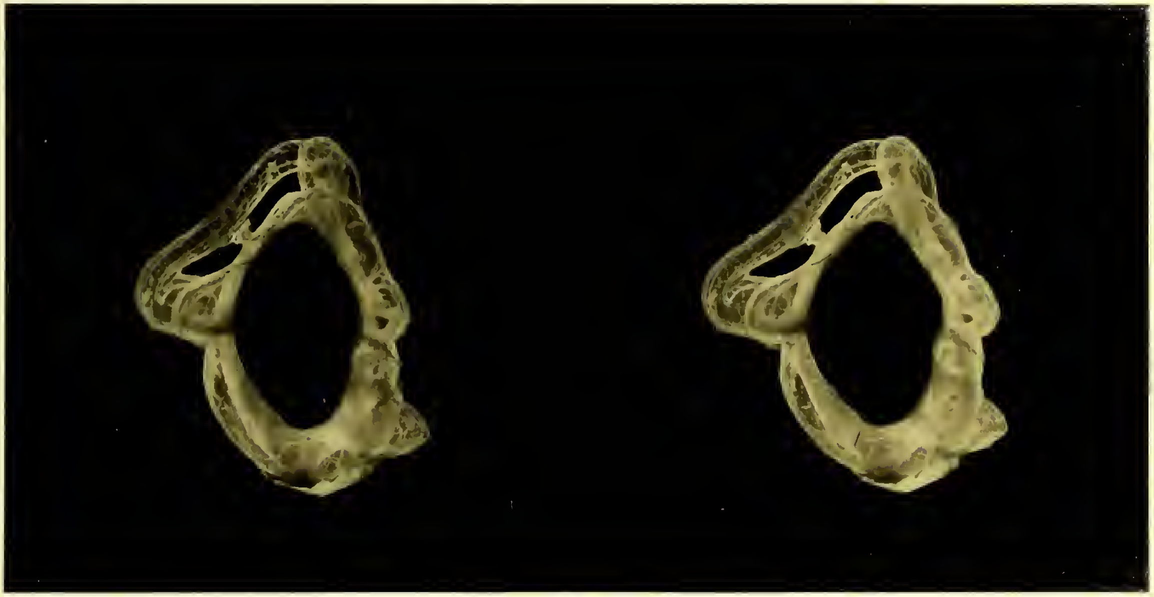
PLATE XLII

THE RIGHT MEMBRANOUS LABYRINTH OF THE WEST AFRICAN PYTHON

Pytho sebæ

× 5¾

The organ is viewed from the inner aspect and in front, and is rotated counter-clockwise to the extent of about 30°. At the right corner of the photograph is the ampulla of the superior canal, and that of the horizontal canal is immediately behind it. There is a communication between the upper surface of the vestibule and the middle of the superior canal similar to that found in the teguixin. The vestibule is very large, and projects downwards and outwards, this portion being termed the recessus labyrinthi. The otolith mass is large and disc-shaped. The small conical cochlea is seen in the lower right-hand corner of the photograph, and on its surface a very few scattered granules of pigment may be seen.



OPHIDIA

BOIDÆ

THE MEMBRANOUS LABYRINTH OF THE WEST AFRICAN PYTHON

Pytho sebæ

In its general appearance the labyrinth of the python shows considerable similarity to those of the lizards just described.

The organ measures 7.5 mm. from the uppermost point on the superior canal to the tip of the cochlea. The *cochlea* has a diameter of 3.5 mm. at its base, and there is a scattered deposit of pigment towards the apex of the organ. In shape the cochlea is that of a blunt cone.

The *vestibule* is a large cavity roughly spherical in shape but flattened slightly from within outwards. The otolith apparatus is very large, and occupies the greater part of the vestibule. It lies almost in the sagittal plane, and is in the shape of an oval disc, the major axis of the ellipse being vertical. It consists of numerous minute crystals, held together by a very delicate semi-gelatinous membrane. The vestibule measures 5.5 mm. in its longest diameter, and the major axis of the oval window has a length of nearly 2.5 mm.

The *superior canal* has internal and external diameters of 3.5 mm. and 6.0 mm. respectively. The height of the canal above the vestibule is 0.75 mm., and the diameter is also 0.75 mm. The *posterior canal* measures 3.0 mm. in internal, and 5.5 mm. in external diameter. The height above the vestibule is 0.5 mm., and the diameter is 0.75 mm. The *horizontal canal* has internal and external diameters of 3.75 mm. and 5.0 mm. respectively. The canal is in contact with the vestibule throughout its whole course, and its diameter is 0.75 mm.

The horizontal canal is curved, but the other two canals are angular, the angles being acute.

In the labyrinth of this snake there is found a little tubular bridge passing from the upper surface of the vestibule to the middle of the superior canal. If examined carefully in a bright light it will be noticed that the little tube is continued up through the perilymph space of the superior canal to the endolymph space. In this curious structure, therefore, we have a point of similarity between the labyrinth of the snake and that of the teguixin.

LITERATURE.—Kuhn, *Loc. cit.* Retzius, *Op. cit.* vol. ii. S. 48.

THE LABYRINTH OF THE AMPHIBIANS

For the reasons stated previously, the writer has been compelled to limit the description of the labyrinth of the amphibians to two examples, and, unfortunately, these both belong to the anura. The reader must remember, therefore, that these descriptions are given rather with the object of demonstrating the organ in amphibians in order that it may be compared with those of the other divisions of the vertebrates. A much larger and more varied amount of material would be required to give even a fairly complete description of the labyrinth of amphibians, since the organ varies considerably in different species. Should the writer ever hav- an opportunity of obtaining this material, he may enter more fully into this portion of the subject at a later date.

PLATE XLIII

THE LEFT MEMBRANOUS LABYRINTH OF THE GIANT TOAD

Bufo marinus

× 12

The organ is viewed from above so that of the three canals the superior is seen to the right, the posterior to the left and the horizontal above. The letters indicate the different structures.

R. L.	Recessus labyrinthi (recessus utriculi).
H.	Horizontal canal.
A. H.	Ampulla of horizontal canal.
S.	Superior canal.
P.	Posterior canal.
U.	Utricle.
A. S.	Ampulla of superior canal.
O.	Otolith apparatus.
N. H. S.	Nerve to ampullæ of superior and horizontal canals.[1]
N. P.	Nerve to ampulla of posterior canal.
N. U.	Nerve to utricle.
C. C.	Common crus of superior and posterior canals.

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[1] The line opposite N. H. S. should be continued eight millimetres to the right.

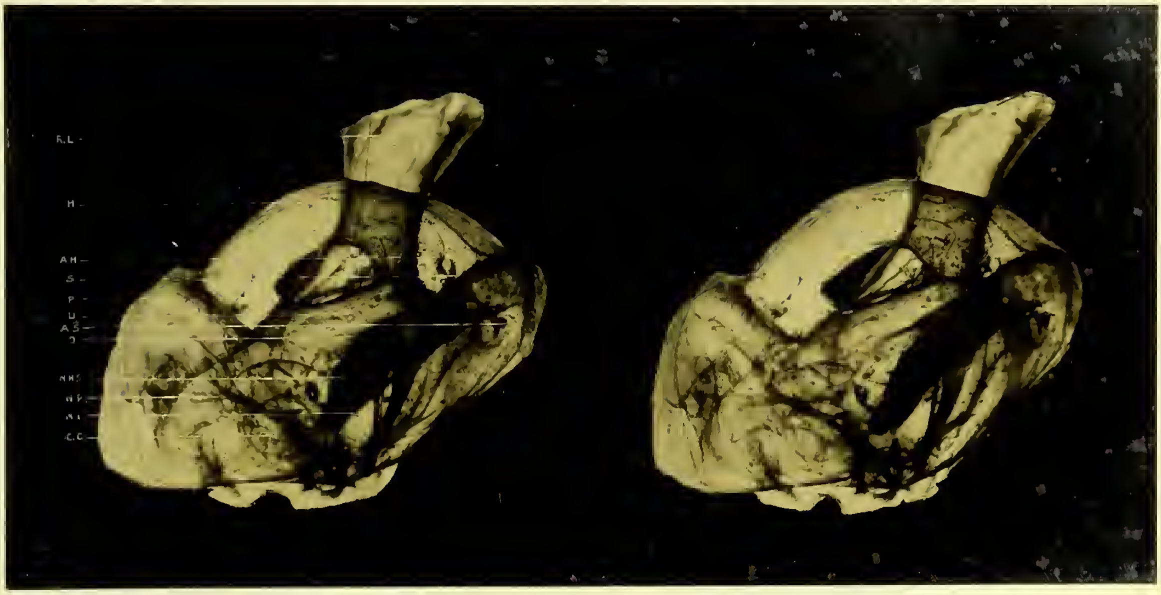

R.L
H
AH
S
P
U
AS
D
NHS
NP
NI
C.C

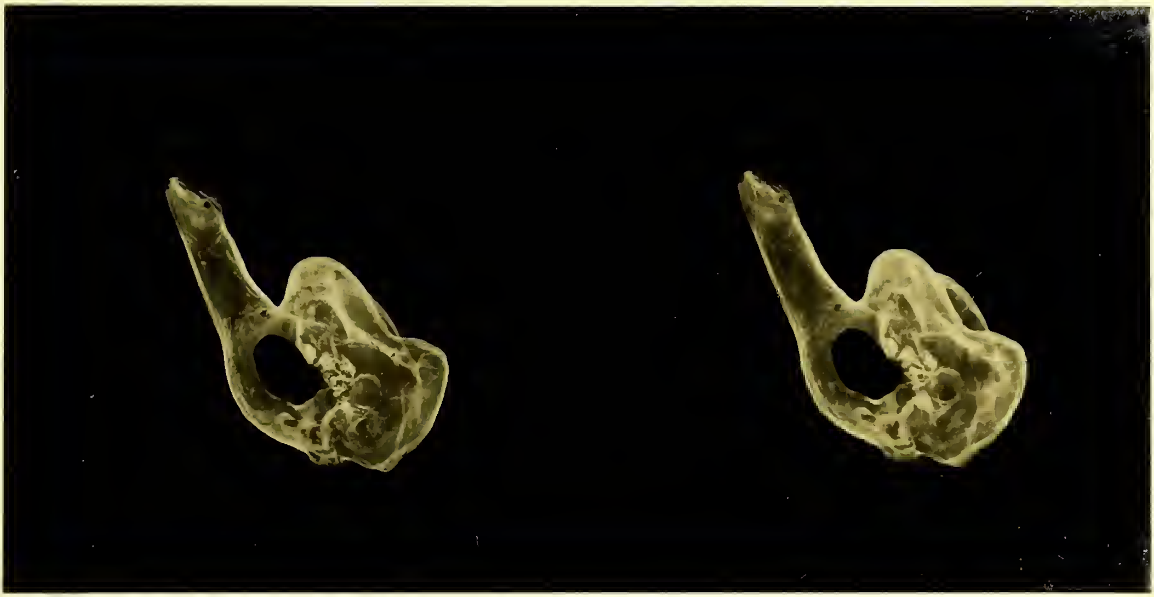
PLATE XLIV

THE LEFT MEMBRANOUS LABYRINTH OF THE GIANT TOAD

Bufo marinus

× 6

The organ is viewed from behind, below and from the outer aspect. It is also rotated clockwise to the extent of about 60°, so that the long tubular recessus labyrinthi should be nearly horizontal. The large black disc in the centre is an otolith mass, and immediately below it, and also with a small otolith mass, is the racquet-shaped macula lagenæ. Downwards and to the right of the latter, but hardly visible in the photograph, is the macula basilaris. To the right of the last named and curving towards the reader, the nerve to the posterior ampulla is clearly seen, as is also its goblet-shaped termination in the ampulla. The pear-shaped structure seen in the photograph beyond the ampulla of the posterior canal is the region of the macula neglecta. Small irregular collections of otoliths are seen as white masses in the vicinity of the larger and denser otolith mass mentioned above. No pigment is found in the labyrinth.



THE MEMBRANOUS LABYRINTH OF THE GIANT TOAD

Bufo marinus

The labyrinth of the giant toad measures 8.0 mm. from the inner surface of the vestibule to the external termination of the recessus labyrinthi, that long and comparatively thick tube which passes from the vestibule outwards, under the horizontal canal. The longest diameter of the *vestibule*, excluding the recessus labyrinthi, measures 5.0 mm.

The *superior canal* measures 3.0 mm. in internal, and 4.0 mm. in external diameter. Its wall is almost, if not quite, in contact with that of the vestibule throughout its whole course. The diameter of the canal itself at the vertex is 1.0 mm. The *posterior canal* has internal and external diameters of 2.5 mm. and 4.0 mm. respectively, and the diameter of the canal itself is 1.0 mm. This canal also is in contact with the vestibule throughout its whole course. The *horizontal canal* measures 2.0 mm. in internal, and 4.0 mm. in external diameter, while the tube itself has a diameter of 1.0 mm. The canal is not quite in contact with the vestibule throughout, but the space between is very small.

The canals of the giant toad are small, thick and curved, thus presenting quite a different appearance from those of the reptiles. The ampullæ are supplied with nerves, but the neuro-epithelium is not divided into the crests which characterise those of the birds and some of the reptiles. The perilymph space of the canals is large.

The cochlea produces no prominence on the outer wall of the organ, but its rudiment is to be seen in the form of two maculæ immediately below the nerve to the posterior ampullæ. Of these the anterior is racquet-shaped, and on its upper surface there lies a small collection of otoliths. This corresponds to the lagena of birds and reptiles. The posterior macula of the two just mentioned is much smaller, is circular in shape, and possesses no otolith ; it corresponds to the basilar portion of the cochlea in birds and reptiles, and to the whole of the cochlea in mammals. The macula neglecta is also found in the toad, and it is supplied by a twig from the nerve to the posterior ampulla, but this twig is not seen in the photograph. The branch to the posterior ampulla passes backward from the main division of the auditory nerve which divides just before entering the labyrinth. The other nerves, which supply the two anterior ampullæ and the vestibule, run forward after leaving the main division, those to the ampullæ being the anterior ones, while that to the utricle runs forward and outwards. The macula of the last-named is covered by the large otolith mass.

Since the labyrinth of the giant toad has never been investigated before, it is necessary to say a few words on the peculiar development of the recessus labyrinthi and its real or apparent communication with the tissues on the outside of the skull.

It will be seen in the photograph that the endolymph space containing the otolith apparatus lies in large part under the horizontal canal. This portion is the recessus utriculi or labyrinthi, and passing outwards from it is a long and fairly wide tube, which opens on the outside of the skull. Thus there appears to be a direct communication between the labyrinth and the outside of the skull quite independent of that found by Coggi in the toad and by Wiedersheim in the gecko, in both of which cases the ductus endolymphaticus is the channel by which the communication takes place.

Were its existence not so startling this discovery of a new communication between the labyrinth and the outside of the skull might be merely recorded, but its very unexpectedness makes the writer view its existence as possibly doubtful. It is therefore necessary to consider whether any error in observation can have been made. The only error that can have arisen is that the tubular canal seen in the photograph may be the tympanic cavity. The absence of the columella does not exclude this possibility, because it was removed before preparation. There is, of course, a wall of membranous or cartilaginous tissue between the labyrinth and the tympanum, and no such wall can be seen in the photograph, the whole appearing on careful examination to be one continuous tube. The only possible source of fallacy therefore is, that the wall separating the tympanum from the labyrinth is rendered invisible by the clearing agent in which the preparation floats. This explanation is very improbable, but, as stated above, every source of error must be excluded before making the definite statement that a communication of the kind described does in reality exist.

The point could of course be settled by the examination of a stained specimen, but unfortunately the giant toad is an animal difficult to procure.

At present, therefore, it may be said that probably a communication exists between the labyrinth of the outside of the skull other than that found in the frog by Coggi, and in the gecko by Wiedersheim, but that further investigation is necessary to settle the point definitely. These remarks also apply to the same apparent communication which is found in the tigrine frog (*v.* p. 236).

As has been remarked above, the otolith apparatus in amphibians, and it may be added, in reptiles also, consists of a granular mass of minute crystals held together by a semi-gelatinous envelope. It is therefore similar to that found in the dipnoid, and quite unlike that of the teleostean and most other fishes. These facts may have some phylogenetic significance. In the otolith of the bird there is a distant resemblance to that of the teleostean fishes, in so far that the crystal is of a size quite sufficient to be recognised by the naked eye in many examples. The true significance of differences in the otolith apparatus cannot be determined until its function is more accurately ascertained. A careful study of the movements of the various animals, according to their rapidity, delicacy and variety, may throw some light on the subject.

LITERATURE.—(See page 237.)

PLATE XLV

THE RIGHT MEMBRANOUS LABYRINTH OF THE TIGRINE FROG

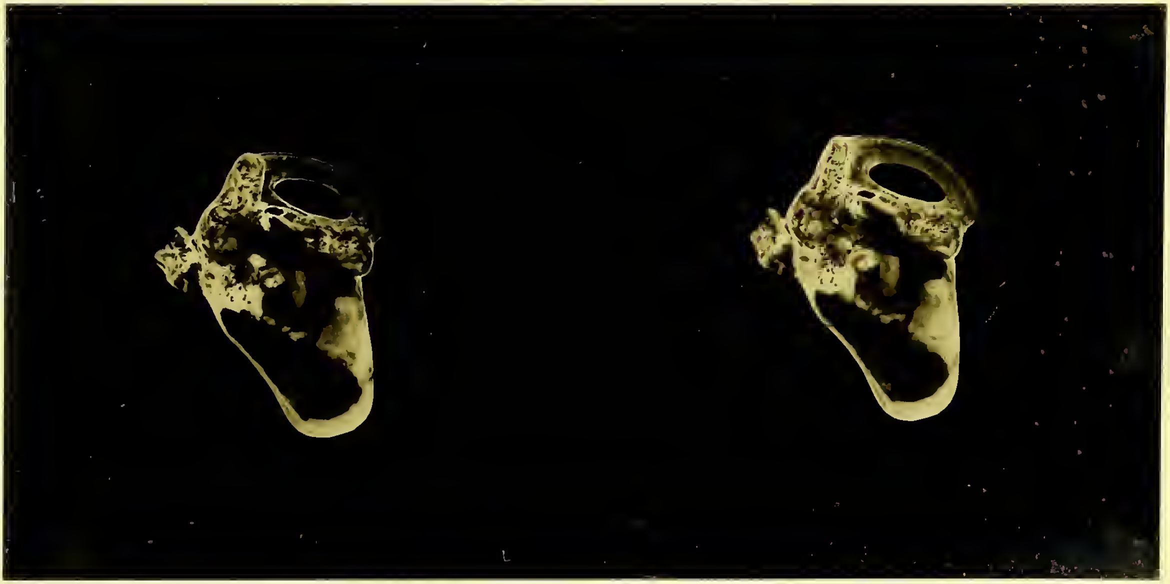
Rana tigrina

× 7

The organ is rotated clockwise to a very slight extent and is viewed from the outer aspect and slightly above. The superior canal is seen above and the posterior behind, the horizontal being below the superior. The perilymph space is well marked in all the canals, and there is a channel of communication between the horizontal and posterior canals at the point at which they cross. The recessus labyrinthi, which forms the largest portion of the whole organ, is seen coming outwards, and on the upper surface of its outer part a small foramen may be seen. This foramen corresponds to the wide opening in a similar position in the toad. The minute crystals which compose the otolith mass have escaped from their gelatinous envelope and may even be traced up to the foramen just mentioned. To the extreme left of the photograph two fine tubes may be seen leaving the labyrinth and uniting at an acute angle. These form the beginning of the curious system of channels described by Coggi (see text), but the rest of that system has been removed in the course of preparation.

The oval window, which is really round, appears oval in the photograph, but this is because it is seen obliquely. It lies under the horizontal canal.

Pigment is seen in scattered granules over the canals and adjacent parts of the vestibule.



THE MEMBRANOUS LABYRINTH OF THE TIGRINE FROG

Rana tigrina

Although the giant toad and the tigrine frog both belong to the Anura, the labyrinths of the two animals show some marked differences.

The organ measures 7.0 mm. in length from the inner surface of the vestibule to the outermost point on the recessus labyrinthi. The longest diameter of the vestibule measures 3.25 mm.

The *superior canal* has internal and external diameters of 2.0 mm. and 3.5 mm. respectively. The height of the canal above the vestibule is rather less than 1.0 mm., and the diameter of the canal itself is rather more than 0.5 mm. The *posterior canal* measures 1.0 mm. in internal, and 3.0 mm. in external diameter. The height of the canal above the vestibule is 1.0 mm., and the diameter of the tube is also 1.0 mm. The *horizontal canal* has internal and external diameters of 2.5 mm. and 3.75 mm. respectively. The height of the canal above the vestibule is 1.0 mm., and the diameter of the tube is also 1.0 mm.

The labyrinth of the tigrine frog is not quite so large as that of the giant toad, and the canals are perhaps rather more regularly curved. In the frog, moreover, there are found scattered granules of pigment over the canals and a portion of the vestibule; these are not present in the toad. In both animals there is a communication between the posterior limbs of the horizontal and posterior canals, a condition, it will be remembered, which is the most common in birds and reptiles, but very rare in the mammalia. The perilymph space is well marked in all the canals; in this respect also the labyrinth of the amphibians agrees with that of the reptiles and the birds, and differs from the majority of the mammalia. Of the three canals the superior is the most angular, and it is of interest to observe that when angularity of the canals is found in the reptiles, birds, or mammals, it is the superior one which shows the condition most frequently and most noticeably; the labyrinths of the gecko, the apteryx, the platypus and the sloth, illustrate this.

Perhaps the feature of most interest in the labyrinth of the frog, as also in that of the toad, is the large recessus labyrinthi, or recessus utriculi, as it is sometimes called. As in the case of the toad, the greater part of the labyrinth is taken up by this cavity, but in the frog it will be noticed that it is broader and ends in a rounded cul-de-sac. Its appearance is that of an irregular cone with the rounded apex directed outwards. A mass of minute otoliths is found in the cavity, but in the specimen from which the photograph was taken the minute crystals had escaped from their gelatinous envelope and become scattered to a certain extent. On the upper surface of the outer portion of the recessus labyrinthi a small opening may be seen if looked for carefully. This corresponds to the comparatively large one, which is seen in the same position in the toad, and by its means there is apparently a communication with the outside of the cranium on the side of the neck. The question as to whether this communication is real or only apparent is discussed on page 231.

In 1890 Coggi made the remarkable discovery that the endolymph space of the labyrinth of the frog extended far beyond the limits which had previously been described. He found that the endolymph sacs of opposite sides are united behind the brain, and from this canal finer ones run backwards above the spinal cord. From these finer canals another set pass outwards through the intervertebral foramina and terminate blindly in sacs containing otoliths. For the demonstration of this system of canals special methods of preparation are necessary, but in Plate XLV. the endolymph aqueduct may be seen leaving the labyrinth on the left side of the photograph, and in Plate XLIV. it may also be seen, though less clearly, at the lowest part of the photograph.

LITERATURE.—Hasse, *Zeitschr. f. wissenschftl. Zoolog.* Bd. xviii. S. 72. Wiedersheim, *Loc. cit.* Retzius, *Op. cit.* vol. i. S. 187, 192. Coggi, *Anatom. Anzeig.* Bd. v. S. 177, 1890. Corning, *Morph. Jahrbuch*, Bd. xxvii. 1899. Harrison, *Internat. Monthly Journ. Anat.* vol. xix. p. 221, 1902.

TABLES

THE DEFINITIONS OF THE TERMS USED IN THESE TABLES ARE GIVEN IN VOL. I. P. 185.

TABLE I.

	Rodentia—*cont.*			
	Common Squirrel (*Sciurus vulgaris*)		Capybara (*Hydrochoerus capybara*)	
	mm.		mm.	
Extreme length of Labyrinth	7.5	1.00	14.5	1.00
Diameter of Lowest Whorl of Cochlea	3.25	0.43	7.0	0.48
Diameter of Second Whorl of Cochlea	2.25	0.30	4.5	0.31
Diameter of Tube of Cochlea in front of Round Window	1.75	0.23	2.5	0.17
Longest diameter of Vestibule	3.0	0.40	5.0	0.34
Internal diameter of Superior Canal	4.0	0.53	5.5	0.37
External diameter of Superior Canal	5.0	0.66	7.5 +	0.51
Height of Superior Canal	3.0 +	0.40	4.75	0.32
Diameter of Tube of Superior Canal at Vertex	0.5 −	0.06	1.0 −	0.07
Internal diameter of Posterior Canal	2.5	0.32	4.75	0.32
External diameter of Posterior Canal	3.25 +	0.43	6.5	0.44
Height of Posterior Canal	2.5	0.32	4.5	0.31
Diameter of Tube of Posterior Canal at Vertex	0.5 −	0.06	1.0	0.07
Internal diameter of Horizontal Canal	3.0	0.40	5.5	0.37
External diameter of Horizontal Canal	3.75 +	0.50	7.5	0.51
Height of Horizontal Canal	2.5	0.32	3.5	0.24
Diameter of Tube of Horizontal Canal at Vertex	0.5 −	0.06	1.0	0.07
Major Axis of Oval Window	1.5	0.20	2.0 −	0.13
Slant Height of Cochlea	2.75	0.36	6.0	0.40
Number of Turns of Cochlea	2¾	—	4¼	—

MAMMALIA.

INSECTIVORA.				CETACEA.				SIRENIA.		MARSUPIALIA.	
Hedgehog (*Erinaceus europæus*)		Common Mole (*Talpa europæa*)		Whale (*Balæna australis*)		Porpoise (*Phocæna communis*)		Sea-Cow (*Halicore australis*)		Brush-tailed Wallaby (*Petrogale penicillata*)	
mm.		mm.		mm.		mm.		mm.		mm.	
.5	1.00	5.0	1.00	25.0	1.00	9.5	1.00	18.0	1.00	8.0	1.00
.0	0.46	2.0—	0.40	20.5	0.82	8.5	0.89	10.5	0.58	4.5—	0.56
.75	0.27	1.0	0.20	12.5	0.50	4.5	0.47	6.75	0.37	2.5	0.31
.5	0.23	0.75	0.15	4.5	0.18	3.0	0.31	3.5	0.19	2.5	0.31
.5—	0.38	1.75	0.35	6.0	0.24	1.25+	0.13	9.0	0.50	4.5	0.56
.75	0.42	2.25	0.45	5.0	0.20	1.5	0.15	7.0	0.38	3.5	0.44
.5	0.53	3.0	0.60	7.5	0.30	2.0—	0.21	8.5	0.47	5.0	0.62
.0	0.46	2.75+	0.55	5.0	0.20	1.25—	0.13	6.0	0.33	3.0	0.37
.5	0.07	0.25+	0.05	0.75	0.03	0.5—	0.05	0.75	0.04	0.5+	0.06
.0	0.30	1.5	0.30	3.5	0.14	0.75+	0.07	4.75	0.26	3.0	0.37
.0	0.46	2.25	0.45	5.5	0.22	1.5	0.15	6.75	0.37	4.5	0.56
.0	0.30	2.25	0.45	4.5	0.18	0.5	0.05	5.0	0.27	3.0	0.37
.5	0.07	0.25+	0.05	0.75	0.03	0.5—	0.05	1.0	0.05	0.5	0.06
.0	0.30	1.5	0.30	6.5	0.26	1.75	0.18	5.0	0.27	3.0	0.37
.25	0.50	2.25	0.45	9.5	0.38	2.25	0.23	7.0	0.38	4.0	0.50
.0	0.30	2.0	0.40	5.0	0.20	1.25—	0.13	5.5	0.30	2.5+	0.31
.5	0.07	0.25+	0.05	0.75	0.03	0.5—	0.05	1.0	0.05	0.5	0.06
.0	0.15	0.5	0.10	6.0	0.24	1.25	0.13	5.25	0.29	1.5	0.19
.5	0.38	1.5+	0.30	13.0	0.52	6.5	0.67	7.0	0.39	3.75	0.47
1½	—	1¾	—	2	—	1¾	—	1½	—	3	—

TABLE I.

	MARSUPIALIA—*cont.*			
	Black-faced Kangaroo (*Macropus melanops*)		Vulpine Phalanger (*Trichosurus vulpecula*)	
	mm.		mm.	
Extreme length of Labyrinth	12.0	1.00	9.0	1.00
Diameter of Lowest Whorl of Cochlea	6.0	0.50	4.0	0.44
Diameter of Second Whorl of Cochlea	3.5 –	0.29	2.75	0.30
Diameter of Tube of Cochlea in front of Round Window	3.5 +	0.29	2.5	0.28
Longest diameter of Vestibule	4.0	0.33	2.75 +	0.30
Internal diameter of Superior Canal	5.75	0.48	4.5	0.50
External diameter of Superior Canal	6.75 +	0.56	5.25	0.58
Height of Superior Canal	6.0	0.50	4.25	0.47
Diameter of Tube of Superior Canal at Vertex	0.5	0.04	0.5	0.05
Internal diameter of Posterior Canal	4.5	0.37	3.0	0.33
External diameter of Posterior Canal	6.0	0.50	4.0 –	0.44
Height of Posterior Canal	5.25	0.43	3.0	0.33
Diameter of Tube of Posterior Canal at Vertex	0.5	0.04	0.5	0.05
Internal diameter of Horizontal Canal	4.0	0.33	2.5	0.28
External diameter of Horizontal Canal	5.0	0.41	3.5 –	0.39
Height of Horizontal Canal	3.75	0.31	2.5	0.28
Diameter of Tube of Horizontal Canal at Vertex	0.5	0.04	0.5	0.05
Major Axis of Oval Window	2.0	0.17	1.5 –	0.16
Slant Height of Cochlea	4.75	0.39	4.0 –	0.44
Number of Turns of Cochlea	2¾	—	3¼	—

AMMALIA.

Marsupialia—*cont.*										Monotremata.	
arsupial Mole (*otoryctes typhlops*)		Pouched Jerboa Mouse (*Antechinomys lanigera*)		Pouched Mouse (*Sminthopsis larapinta*)		Brush-tailed Phascologale (*Phascologale penicillata*)		Short-nosed Bandicoot (*Perameles obesula*)		Duck-billed Platypus (*Ornithorhyncus anatinus*)	
mm.		mm.		mm.		mm.		mm.		mm.	
4.5	1.00	4.5	1.00	4.0	1.00	5.75	1.00	6.5	1.00	10.25	1.00
2.0	0.44	2.0	0.44	2.0	0.50	3.0	0.52	3.0	0.46	—	—
1.25	0.27	1.5	0.33	1.25	0.31	2.0	0.34	2.0	0.31	—	—
0.75 +	0.16	1.0	0.22	1.0	0.25	1.5	0.26	1.75	0.26	1.25 +	0.12
1.5 +	0.33	2.0	0.44	1.75	0.43	2.5	0.43	2.25	0.34	2.75 −	0.26
1.75	0.38	2.25	0.50	1.5	0.37	2.5	0.43	3.0	0.46	3.0	0.29
2.5	0.55	2.75	0.60	2.25	0.56	3.25	0.56	4.0	0.61	4.5	0.43
1.75	0.38	2.25	0.50	1.5 +	0.37	3.0	0.52	3.0	0.46	2.75 +	0.27
0.25 +	0.05	0.25	0.05	0.25 —	0.06	0.5 —	0.08	0.25 +	0.04	0.5	0.05
1.25	0.27	1.75	0.38	1.0	0.25	1.75 +	0.30	2.0	0.30	2.75	0.27
2.0	0.44	2.25	0.50	1.75	0.43	3.0 −	0.52	3.0	0.46	3.5	0.34
1.5 +	0.33	1.75	0.38	1.25	0.31	2.25	0.39	2.25	0.34	3.0	0.29
0.25 +	0.05	0.25 −	0.05	0.25 −	0.06	0.5 —	0.08	0.25 +	0.04	0.75	0.07
1.25	0.27	1.5	0.33	1.0 —	0.25	2.0	0.34	2.0	0.30	2.5	0.24
2.0	0.44	2.0	0.44	1.5	0.37	3.0 —	0.52	3.0	0.46	4.0 +	0.39
1.0 +	0.22	1.5	0.33	1.25	0.31	2.0	0.34	2.0 —	0.30	2.0	0.19
0.25 —	0.05	0.25 —	0.05	0.25 —	0.06	0.5 −	0.08	0.25 +	0.04	0.75 +	0.07
0.5	0.11	0.5	0.11	0.5 —	0.12	1.0 —	0.17	1.0	0.15	1.5	0.14
1.25	0.27	1.75	0.38	1.5	0.37	2.5	0.43	2.75	0.42	*	—
1½	—	1¾	—	1¾	—	2½	—	2¼ —	—	½	—

* In the platypus the cochlea has a length of 3.0 mm. from the front of the round window to the tip.

TABLE II.

	Ratitæ			
	Ostrich (*Struthio Masai*)		Rhea (*Rhea americana*)	
	mm.		mm.	
Extreme length of Labyrinth	18.0	1.00	—	—
Diameter of Tube of Cochlea in front of Oval Window	2.5	0.14	See	text
Longest diameter of Vestibule	3.5 +	0.19	—	—
Internal diameter of Superior Canal	7.5	0.42	—	—
External diameter of Superior Canal	11.0	0.61	—	—
Height of Superior Canal	9.5	0.53	—	—
Diameter of Tube of Superior Canal at Vertex	1.5 +	0.08	—	—
Internal diameter of Posterior Canal	5.5	0.30	—	—
External diameter of Posterior Canal	8.5	0.47	—	—
Height of Posterior Canal	3.5	0.19	—	—
Diameter of Tube of Posterior Canal at Vertex	1.5	0.08	—	—
Internal diameter of Horizontal Canal	4.0 +	0.22	—	—
External diameter of Horizontal Canal	8.5	0.47	—	—
Height of Horizontal Canal	4.0	0.22	—	—
Diameter of Tube of Horizontal Canal at Vertex	1.5	0.08	—	—
Major Axis of Oval Window	2.5	0.14	—	—
Length of Cochlea from Tip to front of Oval Window	6.0	0.33	—	—

AVES.

Ratitæ—*cont.*		Colymbiformes		Ciconiiformes					
Apteryx (*Apteryx mantelli*)		Red-throated Diver (*Colymbus septentrionalis*)		Cape Gannet (*Sula capensis*)		Cormorant (*Phalacrocorax carbo*)		Night Heron (*Nycticorax griseus*)	
mm.		mm.		mm.		mm.		mm.	
10.5	1.00	13.0	1.00	17.0	1.00	13.5	1.00	13.0	1.00
2.0	0.19	2.0	0.15	2.0	0.12	2.0	0.15	1.5	0.12
3.0	0.29	4.5	0.35	4.5—	0.26	3.0	0.22	3.5	0.27
4.0	0.38	6.0	0.46	7.0	0.41	5.0	0.37	5.0	0.38
6.0—	0.57	7.75	0.60	9.5	0.56	7.5	0.56	7.0	0.54
4.5	0.43	5.75	0.44	8.5	0.50	4.0	0.30	5.5	0.42
1.0	0.09	1.0	0.08	1.25—	0.07	1.5	0.11	1.0	0.08
3.0	0.29	4.0	0.31	5.5	0.32	4.0	0.30	3.75	0.29
4.5	0.43	6.0	0.46	8.0	0.47	6.25	0.46	5.25	0.40
2.0	0.19	3.0	0.23	4.0	0.23	2.5	0.19	3.5	0.27
1.0	0.09	1.0	0.08	1.25	0.07	1.25	0.09	1.0	0.08
2.5	0.24	4.25	0.33	4.75	0.28	4.5	0.33	4.5	0.35
4.0	0.38	6.25	0.48	7.25	0.42	6.5	0.48	6.0	0.46
2.5	0.24	3.5	0.27	4.5	0.26	3.0	0.22	3.5	0.27
1.0	0.09	1.0	0.08	1.25	0.07	1.5	0.11	1.0	0.08
1.0	0.09	1.75	0.13	2.0	0.12	1.75+	0.13	1.5+	0.12
2.5+	0.24	4.5	0.35	6.0	0.35	4.5	0.33	4.0	0.31

TABLE II—*cont.*

	ANSERIFORMES		FALCONIFORMES	
	Common Duck (*Anas boscas*)		Common Buzzard (*Buteo vulgaris*)	
	mm.		mm.	
Extreme length of Labyrinth	11.0	1.00	15.5	1.00
Diameter of Tube of Cochlea in front of Oval Window	1.75	0.16	2.0	0.13
Longest diameter of Vestibule	4.25	0.39	4.5	0.29
Internal diameter of Superior Canal	3.0	0.27	5.25	0.34
External diameter of Superior Canal	4.5	0.41	7.25	0.47
Height of Superior Canal	6.0	0.55	7.25	0.47
Diameter of Tube of Superior Canal at Vertex	1.0	0.09	1.5	0.09
Internal diameter of Posterior Canal	3.5	0.32	6.0	0.39
External diameter of Posterior Canal	5.0	0.45	9.0	0.58
Height of Posterior Canal	4.0	0.36	4.5	0.29
Diameter of Tube of Posterior Canal at Vertex	1.0	0.09	1.5	0.09
Internal diameter of Horizontal Canal	3.5	0.32	7.0	0.45
External diameter of Horizontal Canal	5.0	0.45	9.5	0.61
Height of Horizontal Canal	3.0	0.27	4.5	0.29
Diameter of Tube of Horizontal Canal at Vertex	1.0	0.09	1.5	0.09
Major Axis of Oval Window	—	—	2.0	0.13
Length of Cochlea from Tip to front of Oval Window	4.0	0.36	4.5	0.29

AVES.

Falconiformes—*cont.*		Tinamiformes		Galliformes				Gruiformes	
Sparrow Hawk (*Accipiter nisus*)		Great Tinamou (*Rhynchotus rufescens*)		Common Fowl (*Gallus domesticus*)		Red Grouse (*Lagopus scoticus*)		Porphyrio (*Porphyrio calvus*)	
mm.		mm.		mm.		mm.		mm.	
10.5	1.00	9.5	1.00	12.5	1.00	10.0	1.00	12.0	1.00
1.5 +	0.14	1.5	0.16	1.5	0.12	1.25	0.13	2.0	0.17
3.0 −	0.29	2.5	0.26	3.5	0.28	3.0	0.30	4.0	0.33
4.0	0.38	3.75	0.39	3.75	0.30	4.0	0.40	4.5 +	0.38
5.0 +	0.48	5.25	0.55	4.5	0.36	5.5	0.56	6.0	0.50
4.5	0.43	5.5	0.58	6.25	0.50	3.0	0.30	4.5	0.38
1.0 −	0.09	1.0 −	0.11	1.0 −	0.08	0.75	0.08	1.0	0.08
3.5 +	0.33	3.0	0.32	4.0	0.32	3.0	0.30	4.0	0.33
5.75	0.55	4.5	0.47	5.0 +	0.40	4.25	0.43	5.5	0.46
2.75	0.26	2.75	0.29	3.5 +	0.28	2.75	0.28	2.5	0.21
1.0	0.09	1.0	0.11	1.0	0.08	0.75	0.08	1.0	0.08
5.0	0.48	3.5	0.37	4.75	0.38	3.25	0.33	3.75	0.31
7.0	0.67	5.25	0.55	6.0	0.48	5.0	0.50	5.5	0.46
2.25	0.21	2.75	0.29	3.5 +	0.28	2.25	0.23	2.75	0.23
1.0	0.09	1.0	0.11	1.0	0.08	0.75	0.08	1.0	0.08
1.0	0.09	1.0	0.11	—	—	1.5	0.15	1.75	0.15
4.0	0.38	2.75	0.29	3.75 +	0.30	3.5	0.35	4.0	0.33

TABLE II.—*cont.*

	Gruiformes—*cont.*		Charadriiformes	
	Crowned Crane (*Balearica pavonina*)		Common Pigeon (*Columba livia*)	
	mm.		mm.	
Extreme length of Labyrinth	15.0	1.00	11.0	1.00
Diameter of Tube of Cochlea in front of Oval Window	2.0	0.13	1.0	0.09
Longest diameter of Vestibule	3.5	0.23	2.5	0.23
Internal diameter of Superior Canal	6.0	0.40	4.5	0.41
External diameter of Superior Canal	8.0	0.53	5.5	0.50
Height of Superior Canal	6.5	0.43	4.5	0.41
Diameter of Tube of Superior Canal at Vertex . .	1.25	0.08	0.75 +	0.07
Internal diameter of Posterior Canal	4.75	0.32	3.0	0.27
External diameter of Posterior Canal	6.5	0.43	4.5	0.41
Height of Posterior Canal	3.25	0.22	4.0	0.36
Diameter of Tube of Posterior Canal at Vertex. .	1.0 +	0.07	1.0 +	0.09
Internal diameter of Horizontal Canal . . .	4.5	0.30	3.25	0.30
External diameter of Horizontal Canal . . .	6.5	0.43	5.0	0.45
Height of Horizontal Canal	3.0	0.20	3.0	0.27
Diameter of Tube of Horizontal Canal at Vertex .	1.0	0.07	1.0	0.09
Major Axis of Oval Window	1.5	0.10	—	—
Length of Cochlea from Tip to front of Oval Window	4.5	0.30	3.5	0.32

AVES.

Charadriiformes—*cont.*		Cuculiformes		Coraciiformes		Passeriformes			
Crowned Pigeon (*Goura coronata*)		Slender-billed Cockatoo (*Licmetis nasica*)		Burrowing Owl (*Speotyto cunicularia*)		Carrion Crow (*Corvus corone*)		Song-Thrush (*Turdus musicus*)	
mm.		mm.		mm.		mm.		mm.	
13.0	1.00	11.5	1.00	12.5+	1.00	13.0	1.00	8.5+	1.00
1.5	0.12	2.0	0.17	1.5	0.12	1.5	0.12	1.0	0.12
3.5	0.27	3.0	0.26	3.5	0.28	3.5	0.27	2.25	0.26
5.25	0.40	4.5	0.39	6.0	0.48	5.75	0.44	4.0	0.49
7.5	0.58	6.5	0.57	9.5	0.76	7.0	0.54	5.0	0.59
6.75	0.52	3.75	0.33	4.5	0.36	6.5	0.50	4.0	0.47
1.0	0.08	0.75+	0.06	1.0	0.08	1.0	0.08	0.5+	0.06
4.0	0.36	4.5	0.39	4.5	0.36	4.75	0.37	3.0	0.35
6.5	0.50	6.0	0.52	6.0	0.48	6.5	0.50	4.25	0.50
3.5	0.27	3.5	0.30	3.75	0.30	3.0	0.23	2.75	0.33
1.0	0.08	0.75	0.06	1.0	0.08	1.0	0.08	0.5	0.06
5.0	0.38	4.5	0.39	5.0	0.40	6.5	0.50	4.0	0.47
7.0	0.54	6.5	0.57	6.75	0.54	8.0	0.62	4.75+	0.56
2.5	0.19	2.75	0.24	3.0	0.24	4.5	0.35	2.5+	0.29
1.0	0.08	0.75	0.06	1.0	0.08	1.0	0.08	0.5	0.06
1.5	0.12	1.5	0.13	1.75	0.14	1.75	0.13	1.0−	0.12
4.5+	0.35	5.0	0.43	5.25	0.42	3.5	0.27	3.5−	0.41

TABLE III.

	Chelonia	
	Giant Tortoise (*Testudo gigantea*)	
	mm.	
Extreme length of Labyrinth	9·5	1.00
Diameter of Tube of Cochlea in front of Oval Window	4·5	0.47
Longest diameter of Vestibule	6.0	0.63
Internal diameter of Superior Canal	5·5	0.58
External diameter of Superior Canal	7·5	0.79
Height of Superior Canal	1.0	0.11
Diameter of Tube of Superior Canal	2.0	0.21
Internal diameter of Posterior Canal	5·0	0.53
External diameter of Posterior Canal	8.5	0.89
Height of Posterior Canal	1.5	0.15
Diameter of Tube of Posterior Canal	1.5 +	0.16
Internal diameter of Horizontal Canal . . .	5·75	0.51
External diameter of Horizontal Canal . . .	9·0	0.95
Height of Horizontal Canal	1.0	0.11
Diameter of Tube of Horizontal Canal . . .	1.5 +	0.16
Major Axis of Oval Window	2.75	0.29
Length of Cochlea from Tip to Base	3·75 +	0.39

REPTILIA.

Lacertilia.						Ophidia.	
Moorish Gecko (*Tarentola mauretanica*)		Black-pointed Teguixin (*Tupinambis nigropunctatus*)		Stump-tailed Lizard (*Trachysaurus rugosus*)		West African Python (*Pytho sebæ*)	
mm.		mm.		mm.		mm.	
3.0	1.00	9.0	1.00	7.5	1.00	7.5	1.00
1.25	0.41	1.5	0.17	3.5	0.47	3.5	0.47
2.5	0.83	5.25	0.58	5.25	0.70	5.5	0.73
2.75	0.92	5.5	0.61	5.5	0.73	3.5	0.47
3.0	1.00	7.5	0.83	7.0	0.93	6.0	0.80
0.5	0.17	1.5	0.17	0.5 +	0.07	0.75	0.10
0.5 –	0.17	0.75 +	0.08	1.0	0.13	0.75	0.10
1.0	0.33	4.0	0.44	4.0	0.53	3.0	0.40
2.0 –	0.67	5.75	0.64	6.5	0.87	5.5	0.73
0.25	0.08	contact	—	contact	—	0.5	0.07
0.5 –	0.17	0.75	0.08	1.0 –	0.13	0.75	0.10
2.0	0.67	4.25	0.47	5.0	0.67	3.75	0.50
2.75 +	0.92	6.5	0.72	7.0	0.93	5.0	0.67
0.25 –	0.08	contact	—	contact	—	contact	—
0.5 –	0.17	0.75	0.08	1.0 –	0.13	0.75	0.10
—	—	1.5	0.17	2.0	0.27	2.5	0.33
1.5 –	0.50	4.0	0.44	3.5	0.47	3.0	0.40

TABLE IV. AMPHIBIA.

	Anura.			
	Giant Toad *Bufo marinus*)		Tigrine Frog (*Rana tigrina*)	
	mm.		mm.	
Extreme length of Labyrinth . .	8.0	1.00	7.0	1.00
Longest diameter of Vestibule . .	5.0	0.63	3.25	0.47
Internal diameter of Superior Canal .	3.0	0.38	2.0	0.29
External diameter of Superior Canal .	4.0	0.50	3.5 +	0.50
Height of Superior Canal . . .	—	—	1.0 —	0.14
Diameter of Tube of Superior Canal .	1.0	0.13	0.5 +	0.07
Internal diameter of Posterior Canal .	2.5	0.31	1.0	0.14
External diameter of Posterior Canal .	4.0	0.50	3.0	0.43
Height of Posterior Canal . . .	—	—	1.0	0.14
Diameter of Tube of Posterior Canal .	1.0	0.13	1.0	0.14
Internal diameter of Horizontal Canal	2.0	0.25	2.5	0.36
External diameter of Horizontal Canal	4.0	0.50	3.75	0.54
Height of Horizontal Canal . . .	—	—	1.0	0.14
Diameter of Tube of Horizontal Canal	1.0	0.13	1.0	0.14

END OF THE SECOND VOLUME

Spottiswoode & Co. Ltd., Printers, New-street Square, London.

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